T. LYSENKO

SOIL NUTRITION OF PLANTS

Academician
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CONTENTS

Page

SOIL NUTRITION OF PLANTS AND INCREASED AGRICULTURAL CROP YIELDS 5

SOME URGENT PROBLEMS OF THE ADVANCE IN GRAIN AND ANIMAL HUSBANDRY 30

SOIL NUTRITION OF PLANTS AND FERTILIZATION OF FIELDS 48

LET US CARRY INTO EFFECT THE DECISIONS OF THE JANUARY PLENARY SESSION OF THE C.C., C.P.S.U. 72

SOIL NUTRITION OF PLANTS 108

SOIL NUTRITION OF PLANTS AND INCREASED AGRICULTURAL CROP YIELDS*

The question of nourishing animals and plants is of paramount importance for agricultural science and practice. Everybody knows that the fodder supply is one of the main conditions for the development of stock-breeding. Soil fertility holds an analogous position with regard to plant-growing. The better the fodder supply the greater the amount of livestock products. The more fertile the soil the bigger the crops. The greater the yield of agricultural plants the more possible it becomes to establish a fine fodder supply for animal husbandry.

Fertilizing the soil provides suitable conditions for the nutrition of agricultural plants. This is very important for raising food and industrial crop yields and setting up an adequate fodder supply.

The decision of the September 1953 Plenary Session of the Central Committee of the Communist Party of the Soviet Union states the following with reference to fertilization:

"One of the chief reasons for the low yields of cereal, oil-bearing and industrial crops in a number of areas of the country is that the soil does not receive sufficient organic and mineral fertilizer, particularly manure, peat and peat

* From a paper read at the September 15, 1953 session of the Lenin Academy of Agricultural Sciences of the U.S.S.R.

compost. Because of the lack of proper manure storage facilities in collective farms, the manure is improperly kept and loses its quality. In the Byelorussian S.S.R. and the Bryansk, Smolensk, Velikiye Luki and other regions, lupine, serradella and other green manure crops are planted to an extent far too small. In areas with acidic sod-podzol soils, most of the collective farms do no liming."*

On improving field fertilization the decision of the Plenary Session states:

"Accumulation and application of local fertilizers (dung, peat, liquid manure, compost, etc.) shall be more extensively practised. In regions where there are deposits of peat, its procurement for manuring and littering shall be increased. The preparation and application of composts and organic-mineral mixtures shall be organized on a large scale, so that within the next two or three years the amount of organic fertilizer used by the collective farms will be one and a half times or twice as great as in 1952.

"In 1954-63 the Ministry of the Chemical Industry and the Ministry of the Metallurgical Industry shall take measures to increase the mineral-fertilizer producing capacity to roughly 16.5-17.5 million tons in 1959, and to 28-30 million tons in 1964 (in terms of standard units). Output of granulated superphosphate shall be raised to 45 per cent of total superphosphate output in 1955 and to 60 per cent in 1958. From 1956 on, ammonium nitrate shall be supplied to agriculture only in granulated form. The question of broadly utilizing Khibini apatites and local phosphorites for agricultural purposes has to be investigated.

"The U.S.S.R. Ministry of Agriculture and Procurements and the U.S.S.R. Ministry of State Farms and also the local Soviet and agricultural organs shall take measures to ensure the more efficient storage and utilization of mineral fertilizers, so as to prevent losses.

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* *Measures of the Further Development of Agriculture in the U.S.S.R.*, Moscow, 1954, p. 40.—*Ed.*

"In view of the great importance of liming acidic soils and gypsuming saline regions as an important means of increasing crop yields, the Councils of Ministers of the Union Republics shall, beginning with 1954, take measures considerably to increase the production of lime for agricultural purposes by the plants of the building-materials industries, the local industries and the producers' co-operatives, and at the same time reduce the price of lime."*

The above statement shows the vast importance of fertilizing fields, as well as of liming acidic soils and gypsuming saline soils.

Yet the department dealing with this salient problem of the soil nutrition of plants—fertilization and liming—is in my opinion still the most backward department of agrobiology. Soil nutrition of plants is of such pre-eminent importance that even a minute scientific achievement in this sphere may and does exert a beneficent influence on the development of practical plant-growing and on various departments of agricultural science.

The problem of the soil nutrition of plants—i.e., of the nourishment obtained by plants from the soil—and of the use of fertilizer has hitherto been little worked upon scientifically; however, many scientific workers, such as plant-breeders and agrotechnicians, as well as agrochemists and biochemists, fancy that in the field of plant alimentation everything has already been clarified. But I am inclined to think that if certain men of science have no clear notion of what they do not yet know in their particular department of work, it is a sign that even what they do know does not reveal the essence of the processes going on in the phenomenon under discussion.

In actual fact even today agronomic biology has no biological conception of plant nutrition. In agronomy a purely chemical conception of plant nutrition is mistaken for a biological conception. According to the chemical conception,

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* *Ibid.*, pp. 46-47.—*Ed.*

the process of soil nutrition consists in the absorption by the roots of anions and cations of water-soluble inorganic salts required by the plants in definite proportions. Thus the biological process of plant nutrition is still examined in agronomics from the chemical aspect only.

Chemists have already acquired in this regard considerable knowledge of great value and the chemical industry has begun to utilize this knowledge in manufacturing huge quantities of mineral fertilizer in forms that plants can assimilate directly. Practice has confirmed the theory that correctly applied mineral fertilizers are a potent factor increasing crop yields. But mineral fertilizers will beyond a doubt prove still more beneficial if the nutrition process of plants is investigated not only from the chemical aspect but also as a biological process, which in fact it really is.

I do not think any scientist will deny that animals and plants have much in common in their bodily structures and that these common features manifest themselves in their chemical and physical processes. However, science—here the physiology of animal nutrition—does not consider the latter merely a chemical process although the physiology of animals has been investigating quite a few chemical processes, and with success, too. Moreover, no one ever entertained the thought of giving animals only water-soluble food.

Herbivorous and omnivorous animals live on food the bulk of which is not water-soluble, although water-soluble substances are required for building up water-insoluble animal as well as plant bodies.

The building up and growth of animal and plant bodies from food take place in a chain of physiological processes and different food conversions, including the conversion of water-insoluble chemical substances into water-soluble ones.

Consequently, the nutrition of animal and plant organisms is a physiological process, a link in the general biological metabolism circuit in inorganic and organic nature. Everybody knows that physiological and, in a more general

sense, *biological processes always take place by the agency of chemical and physical processes.* Biological processes are inseparable from physical and chemical processes. But it would be a mistake to reduce biological laws to chemical or physical ones, or to identify them.

Materialist science accepts it as an indisputable fact that physiological, hence biological processes take place on the basis of biological laws.

Agrochemists and biochemists must continue their fruitful research, must investigate the chemism of biological nutrition processes. The scientific work already referred to has been of use. But it has not revealed the biological laws of plant and animal nutrition. It discloses merely the chemistry of plants, the chemistry of foods and soils. The discovery of biological laws should be and has become the business of Michurinist agrobiology carried on in close contact with practical farming.

The biological laws governing the procurement of nutrients by plants from the soil find expression in the necessary interconnection between plants (or, to be more exact, between their root systems) and a definite complex of environing soil conditions. If the complex needed by a particular plant exists the latter normally satisfies its soil nutrition requirements.

Soil which possesses, in regard to both quality and quantity, the entire complex of conditions required by a given plant is regarded as good and fertile. Fertility is precisely the property which mainly distinguishes soil from bedrock. Academician V. R. Williams, the soil specialist, revealed more lucidly than anyone else the general laws of soil formation, the laws of soil development from elements of bedrock and of the atmosphere owing to the vital functions of micro-organisms, plants and animals. Taking as its basis the laws, already discovered by science and verified in practice, of soil development and of the development of the soil's main property, its fertility, the laws of the decline and restoration of the conditions of soil fertility, Michurinist

biology must work out solutions for problems of practical importance in the sphere of soil nutrition for various agricultural plants.

The science of agriculture must pursue further its research into the biological, natural interconnections between plants and their soil environment—an essential factor of plant nutrition—and must use the results achieved as the basis for elaborating agrotechnical ways and means of improving plant nutrition, enhancing crop yields, facilitating farm work and making it more productive.

I need not dwell in this paper on such universally known facts as that plants need soil moisture and that by diverse agrotechnical methods moisture is accumulated and saved as reserves in the soil or is removed from the soil if superfluous. Let us analyze the soil nutrition of plants from the angle of the natural interconnections between the root systems of the plants and the microflora of the soil.

MICRO-ORGANISMS AND PLANT NUTRITION

Soil scientists and scientific farmers have long been aware of the fact that among the conditions that determine the efficacious fertility of the soil there are conditions that make possible the vital functions of soil micro-organisms. Without the vital functions of appropriate soil micro-organisms the soil does not contain the food the plant requires. Consequently, in the absence of such favourable activity, the soil becomes a barren substratum for the plants in question.

As a result of the diverse influences exerted by the products of the vital activity of various soil micro-organisms, certain elements of inorganic and organic nature, which exist in a form unsuitable for plant nutrition, are changed into forms suitable for plant nutrition, and vice versa.

The vital activity of soil micro-organisms and their mutual interconnections as well as their interconnections with

the root systems perform in the soil nutrition of plants the same function as the digestive system in animal organisms.

The organs and tissues of an animal organism feed on various substances which they need and which they absorb in an assimilable form from their digestive tract, which receives the food from the external environment in forms unfit for direct assimilation by the body of which the organs and tissues are part.

Thus it is the job of the digestive system to convert food from forms unfit for assimilation into forms that can be assimilated by the living body. In plant nutrition the same function is performed by the soil micro-organisms, which change the inorganic and organic elements and substances existing in forms unfit for assimilation by plants into assimilable forms.

Microbiologists have authentically established that in fallow sections, where the soil has been cultivated but not planted, the micro-organism complexes differ from those which inhabit similar soils but covered with vegetation. The complexes differ in respect to both quantity and quality.

In the root zones of plants there are more micro-organisms than in similar soil free from living roots. Besides, a number of species of soil micro-organisms display energetic vital activity, but beyond the root zone these species do not exist at all or their vital activity is greatly reduced.

We know that on the roots of all species of plants belonging to the leguminous family there are nodule bacteria assimilating nitrogen from the air. A specific species of these bacteria is characteristic for each species of the family mentioned. Neither the given leguminous species nor its specific nodule-bacteria species can develop normally without each other.

The same phenomenon has been observed also in many species of other families of herbaceous and arboreal plants, with whose root systems specific species of mycorhizal fungi are connected. In those cases, too, the plants feed badly and develop badly in the absence of mycelia on their

roots specific for the plant species in question. Such plants and the mycorhizal fungi specific for them will not develop normally without each other.

There are also plants in regard to which neither the characteristic nodule bacteria nor the connected mycorhizal fungi have yet been brought to light. But in the zones of their root systems soil micro-organisms specific for these plant species have been ascertained.

The time has come when it is not only possible but, in my opinion, even necessary for general science and practice to lay down the proposition that *there are natural interconnections between the root systems of all plant species and species of soil micro-organisms specific for each plant species or group of related species.* Without such interconnections it is impossible for plants or the soil micro-organism species connected with them to feed or develop normally. Hence there are ample prospects of working out considerably more rational methods of fertilizing fields, of thus raising the yields of all crops, and of simultaneously improving soil fertility. Practice and science show that only by raising big crops every year can soils of low fertility be transformed into soils of high fertility.

Michurinist biologists realize that micro-organism species which normally cannot live outside the roots specific for these micro-organisms or without the root excretions of these plants, are also interconnected with other vitally necessary environmental factors of inorganic and organic nature. The same applies of course to the root system of plants. It has indispensable mutual connections not only with the species of soil micro-organism already ascertained but also with a number of others not yet ascertained, through whose enzymic action unassimilable forms of substances and elements of the organic, mineral and atmospheric environment turn into forms that the plants can assimilate.

Transformations of inorganic substances into organic and, vice versa, of organic into inorganic, can be effected

only in a long chain of interconnections of biological species with one another and with their mineral and atmospheric environment, as well as with the dead organic matter. This is the circular course, the exchange of substances between living and non-living nature. The more fully science discloses the interconnections existing here, the easier will it be to work out agrotechnical ways and means of directing natural processes into channels leading to bigger crops of plant species we stand in need of. Differences obtained in organic and inorganic phenomena, objects, bodies are effected only by the difference in interconnections in the complicated chain of the process of metabolism (conversion of substances) in nature.

Changes in such interconnections bring it about that soils may improve or deteriorate, yields may rise or fall, certain plant and animal species may turn into other species, etc.

In the creation, in the soil, of nutrients for plants, in converting unassimilable and water-insoluble forms of elements and organic and inorganic substances into forms that plants can assimilate, *the existence of specific complexes of soil microflora is*, as has already been stated, *the paramount factor for every species of plant and for every group of plant species*. By setting up the conditions necessary for the normal vital activity of these complexes of soil micro-organisms we create the basis for soil fertility.

It often happens that soils of low fertility lack only a small group of factors essential for the normal vital activity of a complex of useful soil microflora. Practically only a trifle is missing in certain cases. And the agricultural plants cultivated on such soil go hungry and yield bad harvests only on account of that trifle. One need only remove this defect to bring about an improvement in plant nutrition and effect considerable harvest gains, while the soil becomes more fertile.

Carbohydrates, including cellulose, are essential elements of the life and nutriment of a number of useful soil micro-

organisms, and part of the products of their vital activity is essential for feeding other micro-organisms. Therefore, when the soil contains, for instance, no carbohydrates (cellulose), there will be no development of the vital activity of even those useful micro-organisms which do not feed directly on cellulose and do not decompose it. Thus microbiologists have shown that if pure cellulose (filter paper) is converted into glucose by cellulose bacteria, other bacteria species (azotobacteria) turn atmospheric nitrogen by the use of glucose into ammonia nitrogen and organic nitrogen. Consequently, if the necessary conditions are provided, one may, figuratively speaking, by the use of a complex of microflora, transform cellulose (straw) into nitrogenous food for plants.

The examples cited prove that for the proper nutrition of agricultural plants and the simultaneous enhancement of soil fertility the important thing is that only the essential substances (fertilizers) should be introduced, and that the soil conditions now deficient but needed for the normal vital activity of the soil microflora promoting the plant's nutrition should be established. But there must be no full return to the soil of all the crop took from it. Agricultural practice must solve the problems of the soil nutrition of plants, taking into account the part played by the useful microflora in this process. Any other solution is economically unprofitable. Without the aid of corresponding soil micro-organisms it is difficult to nourish plants even with ready forms of food that can be assimilated. This can be done only in experiments with water cultures. Soils may contain, and as a rule do contain, great reserves of plant-food elements in water-insoluble forms and forms plants cannot assimilate. When the desired conditions exist these forms of substances are converted by the micro-organisms into food the plants can assimilate.

A scientific analysis of the various methods of tilling the soil, as applied in practical agriculture, and also the alternation of plants in crop rotations lead to the conclusion

that both tillage methods and plant alternation in crop rotation greatly tend to create conditions that support the vital activity of micro-organisms promoting the soil nutrition of plants, and to suppress the vital activity of micro-organisms harmful to plant nutrition.

This is the point of view from which methods of treating soils with various mineral and organic fertilizers must be worked out.

But it does not follow in the least from what we have said that one should not use fertilizers ready to be assimilated by plants, such as, for instance, easily assimilated mineral nitrates and phosphates. All we said was that, in the main, plant nutrition takes place, and must take place, by the agency of the microflora, and therefore it is important that the latter should be ensured the necessary conditions, including the presence of the deficient nutrient elements in the particular soil.

In the non-chernozem regions a considerable portion of the soil suffers from an excess of acidity. In soil that is not strongly acidic its organic part (root and stubble refuse) and certain inorganic substances of the soil as well as the applied fertilizer are transformed by the pertinent micro-organisms into assimilable plant food.

On acidic soils, however, the vital activity of the microflora useful to agricultural plants is reduced. Soil bacteria, the products of whose vital activity serve as food for agricultural plants, usually do not inhabit the soil if its acidity exceeds a definite standard (usually when pH is lower than 4.5). Acid soils therefore hold little food fit to be assimilated by plants, in particular little nitrogenous and phosphoric food.

Experiments demonstrate that if it is possible to secure in some way or other the existence of food that agricultural plants can assimilate, the plants develop normally and become very hardy. Under such conditions clover and winter wheat overwinter in fine shape and yield big crops.

GOVT. OF INDIA
LAL BAHADUR

This indicates that in itself soil acidity is not injurious to agricultural plants or their root systems. The harmful effect of an acid-soil environment on agricultural plants is due to the circumstance, already mentioned, that bacteria whose vital-activity products serve as food for these plants cannot live in it.

When mineral fertilizer is applied to acidic soils, conditions must be created in them that will make possible the vital activity of the micro-organisms that are of use to agricultural plants. Otherwise such an excellent mineral fertilizer as, for instance, superphosphate will become largely inaccessible to plants growing on acid soils.

In solving the problem of yield improvement on acidic podzol soils one should always bear in mind that it is the products of the vital activity of the micro-organisms that create the soil acidity itself, provided the soil does not contain calcium, which neutralizes this acidity.

Therefore on leaching (washing) calcium carbonate out of the soil the latter is somewhat acidulated by the acids which various micro-organisms generate. In general, soil acidity and alkalinity, in fact the entire soil is the result of the interaction of the vital activity of plants and micro-organisms on the one part and of the mineral elements of the bedrock on which the soil in question is formed on the other.

On lowering soil acidity by introducing lime as a neutralizing agent, a considerable improvement in agricultural-plant development may very often be observed.

This acidity reduction requires from 3 to 5 tons of lime and more per ha. But it has been established long ago by practice—and this is the most important thing—that unless simultaneously with the liming good crops of perennial grasses are raised on the acidic podzol soils, the acidity of such soils will, within a few years after the liming, return to the same level as before the liming.

It has therefore long been established practically and theoretically that when liming acidic podzol soils the

latter must without fail be sown to good perennial-grass crops, which enrich the soil with organic substances. As such soils contain exceedingly small quantities of organic substances (essential food for useful soil microflora) and phosphorus, which plants can assimilate, the liming of acidic soils must be supplemented not only by perennial-grass (clover) sowing but also by dunging such soils and treating them with mineral fertilizer (superphosphate). If this is done fine integumentary grain crops and in subsequent years fine perennial-grass crops are obtained after liming.

A very small amount of nitrogen, sulphur and particularly phosphorus in a form that plants can assimilate is found in acidic soils because of the greatly lowered vital activity of the microflora. Hence the *use of phosphorus fertilizer* when liming strongly acidic soils and with less acidic soils even without liming is an *absolute condition for obtaining good crops*, especially of clover, lucerne and winter wheat.

But experience and practice have shown that the introduction of powdered superphosphates into acid podzol soil with and without liming is little effective. Phosphoric acid is as a rule almost wholly absorbed by the soil without any benefit to the plants. In these cases the micro-organisms, whose vital-activity products constitute an indispensable link in the chain of the biological processes of plant nutrition, are likewise unable to make use of phosphoric acid for lack of dead organic matter in the soil, matter that is essential to life for a number of micro-organisms, or the micro-organisms are unable to develop on account of the high acidity of the soil. Hence phosphoric fertilizer should be used for acidic soils in a form permitting the phosphorus to be utilized as quickly as possible by the useful microflora, whose vital-activity products the plants feed on.

Experiments have shown that the most rational way of treating acidic podzol soils, with or without liming, is to give them powdered superphosphate with at least a slight admixture of, say, humus or peat drenched with liquid

manure, or, still better, with an admixture of good compost. However, powdered superphosphate not mixed with organic matter has little effect.

The high efficiency of superphosphate mixed, for instance, with a relatively small amount of humus or peat is due to the fact that nidi of microflora beneficial to the plants form around the bits of organic matter impregnated with the water-soluble part of the superphosphate.

In spite of the fact that the soil solution and the soil itself are acidic and therefore worthless as regards the life of the microflora, the acidity of the humus particles is not high. For this reason the bacterial flora of the soil, as a number of experimenters have shown, find around these bits of humus impregnated with the soluble part of superphosphate good conditions for their vital activities. Under these conditions plants cultivated even on comparatively acidic soil develop well, as they feed on the phosphorated products of the vital activity of the bacteria.

THE GORKI LENINSKIYE EXPERIMENTS

For the last four years about 120 kg. of superphosphate, mixed with 400-800 kg. of humus per ha., have been put into the loamy acidic podzol soils of the experimental farm of the Lenin Academy of Agricultural Sciences of the U.S.S.R. at Gorki Leninskiye, near Moscow, during the pre-sowing cultivation of soil under winter wheat. In spring they nourish the soil additionally with potassium and nitrogen fertilizer (4 centners per ha.). The resultant crops, with non-fallow preceding crops, registered 20-28 centners per ha. and with fallow predecessors 30-36 centners per ha. These figures are on a par with crops obtained on such soils with the land lying fallow and receiving 30-40 tons of manure per ha. Hence, in the above cases, 3 centners of superphosphate mixed with 1-2 tons of humus take the place of 30-40 tons of manure.

If powdered superphosphate is used without the admixture of 1-2 tons of humus or peat and the soil is not given any manure, then, other things being equal, winter wheat will yield a considerably smaller crop, usually not more than 10-15 centners. The frost-hardiness of winter wheat will also be considerably reduced, and this not infrequently ends in ruined crops in winter or in early spring.

Manure put on fallow fields in the amount of 30-40 tons per ha. was even in the distant past considered the best fertilizer for podzol soils and is still considered as such. It is well known that for such doses of this fertilizer liming is required only with strongly acid soils. Where they are of medium acidity and adequately manured, liming, if required at all, is done very sparingly, the dosage being 1-1.5 tons per ha.

But providing all podzol soils with big doses of manure at frequent intervals (best every year) requires, firstly, very much manure and, secondly, extensive transport facilities and means for delivering and evenly spreading the fertilizer over the field.

The quantity of good organic fertilizer can and must be considerably increased (it can and must be doubled and trebled) in comparison with the amount of manure obtained up till now. For this purpose extensive use must be made of the peat of up-river bogs for animal litters and the composting of down-river bog peat with manure, including liquid manure, must be considerably increased and improved.

Increasing manure and compost production and improving their quality are tasks of the utmost importance. They call for the mechanization of the production, drying, delivery, and spreading of organic fertilizers (manure, compost) over the fields.

Besides considerably augmenting manure and peat-manure compost output, we must also apply more mineral fertilizer, particularly lime and phosphorated fertilizer—superphosphate, as well as ground phosphorite. We consider it must advisable to put on lime and mineral

phosphoric fertilizers after mixing them with organic fertilizers. Proportions of the components of such mixtures, dosages, time of application and soil depths will be discussed below.

The experiments performed in 1953 by Academician A. A. Avakyan on the experimental farm of the Lenin Academy of Agricultural Sciences of the U.S.S.R. at Gorki Leninskiye fully confirmed the great importance of correctly using fertilizer to increase crops in the non-chernozem zone. Let me quote a few experiments with winter wheat (see table).

Experiment with Winter Wheat 1160 at Gorki Leninskiye in 1952-53

Quantity of fertilizer used per ha.	Crop (in centners per ha.)
10 t. lime*	22.2
10 t. lime + 3 centners superphosphate	24.0
5 t. lime	22.6
5 t. lime + 3 centners superphosphate	25.2
control	17.8
1.8 t. humus	24.1
1.8 t. humus + 3 centners superphosphate	27.4
3 centners superphosphate	22.0
1.8 t. humus + 3 centners superphosphate + 3 centners lime	28.7
3 centners lime	19.9
1.8 t. humus + 3 centners lime	27.3

In the experiment under discussion, winter wheat was sown in the autumn of 1952 on unfallowed land after barley as a preceding crop. The soil was podzol with rather high acidity. From plots not fertilized before sowing 17.8 centners of wheat per ha. were obtained. But plots fertilized before sowing with 1.8 tons of humus mixed with 3 centners of superphosphate and 3 centners of ground limestone yielded 28.7 centners of wheat per ha.

* Ground limestone.

Consequently, owing to the small doses of the fertilizer mixture, the excess crop amounted to 10.9 centners per ha. It may be retorted that in this case quite a bit of superphosphate—3 centners per ha.—was used.

But when the same experiment was performed on two other plots which were given 3 centners of pure superphosphate per ha., i.e., not mixed with humus and lime, the crop was equal to 22 centners of wheat grain per ha., i.e., 6.7 centners less per ha. than was obtained from the plots on which the same amount of superphosphate, namely 3 centners, was used, but with an admixture of 1.8 tons of humus and 3 centners of ground limestone. The plots that were given 1.8 tons of humus mixed with 3 centners of superphosphate but no lime yielded 27.4 centners per ha.

The most interesting point in this particular experiment is the finding that plots given 1.8 tons of humus per ha., mixed with 3 centners of lime, without the addition of superphosphate, yielded the same good crop, namely, 27.3 centners per ha., i.e., 9.5 centners more per ha. than plots that did not receive any fertilizer.

Such experimental results compel every scientific worker, every agronomist, to draw the conclusion that the effect will be considerably greater if phosphoric fertilizers (ground phosphorite and powdered superphosphate), as well as lime fertilizers, are introduced into podzol soils not in their pure form but invariably mixed with at least small amounts of organic fertilizer.

As a matter of fact, if in the pre-sowing cultivation of the soil for winter wheat 1.5-2 tons of organic fertilizer mixed with 3 (better 5) centners of limestone material are introduced, the grain crop may be increased in weight by half the dosage of the cheapest agricultural fertilizer put in the soil.

The importance of employing lime mixed with organic fertilizer becomes apparent from the fact that plots which in this experiment were given the same dose of 3 centners of lime not mixed with organic fertilizer produced only

19.9 centners per ha., while plots which received 5 tons of lime per ha. not mixed with organic fertilizer produced 22.6 centners of wheat per ha.

Hence the introduction per ha. of 3 centners of ground lime mixed with 18 centners of humus had a much better effect than putting in 50 centners of ground lime without the addition of any organic fertilizer. In the first instance the crop registered 27.3 centners per ha., in the second, 22.6 centners.

As already stated, at Gorki Leninskiye a mixture of organic fertilizers and mineral phosphoric fertilizers without any addition of lime has been introduced for four years now into the pre-sowing cultivation of land for winter crops planted for production. This four-year production experiment has fully confirmed the advisability and great effectiveness of this method.

It should be noted that on control and experimental plots, the nitrogen and potassium background was on a par in the production crops. The usual dose was one centner of nitrogen and of potassium fertilizer per ha. Every year some of the autumn-ploughed fields were limed. Sometimes lime was spread over sown clover.

And now I shall explain the results of some production experiments obtained in 1953 with regard to the application of superphosphate mixed with humus.

A 5-ha. section of land that had produced a crop of spring wheat was sown in the autumn of 1952 to winter wheat. On a plot of 0.5 ha. no fertilizer was used before sowing. The cereal crop produced by this plot amounted to 20.3 centners per ha. A neighbouring plot, also 0.5 ha. in size, was given, before sowing, 3 centners of powdered superphosphate per ha. Here the yield was 27.3 centners per ha. Along one side of these plots a section holding 1.8 ha. was situated and along the other side there was another section of 2.2 ha. Both sections were treated during the pre-sowing cultivation with a fertilizer mixture consisting of 1.5 tons of humus and 3 centners of superphosphate

per ha. The crop obtained from the first section amounted to 34.3 centners per ha. and from the second to 39.3 centners per ha. So in this experiment too a superphosphate mixture with only 1.5 tons of humus resulted in a crop excess of 7 centners of winter wheat per ha. on the one section and of 12 centners on the other section, if the yields are compared with those of land on which only superphosphate was applied.

On another plot, comprising an area of 11.5 ha. and considerably less cultivated than the previous one, the following bunker crop of winter wheat was obtained: From 1.5 ha. over which no fertilizer was spread the grain yield was 10 centners per ha. An adjoining section of 1 ha., in which 3 centners of powdered superphosphate were inserted before the ground was cultivated for sowing, produced 14.6 centners per ha. Alongside these two sections there were two other sown fields, one of 2.7 ha. and the other of 6.3 ha., on which during the pre-sowing cultivation the following mixture per ha. was introduced: 3 centners of powdered superphosphate and 15 centners of humus. The 2.7 ha. section grew 23.4 centners per ha., the 6.3 ha. section 21 centners per ha.

Thus we see that in this case too the introduction during the pre-sowing cultivation of 3 centners of superphosphate mixed with 15 centners of humus per ha. increased the crop in the one instance by 6.4 centners and in the other by 8.8 centners per ha. when compared to crop yields on sections treated with pure superphosphate. It should be clear to everyone that if in this experiment at least 3 centners of limestone fertilizer had been added to the above mixture of 1.5 tons of humus and 3 centners of superphosphate per ha., the results would have been still better. The experiments show that very effective results are achieved by the introduction into podzol soil of mixtures not only of superphosphate and lime plus organic fertilizer but also of ground phosphorite with organic fertilizers—humus, rotten manure or peat suitable for fertilization.

FERTILIZE ALL FIELDS UNDER CROP

Taking the above as our premise we recommended that in 1953 the collective and state farms should widely check the experiment of introducing mixtures of organic fertilizer with mineral phosphoric and lime fertilizers for winter crops during their pre-sowing soil cultivation. It was recommended to introduce these fertilizers into fields that had not been fertilized.

Among phosphoric fertilizers we suggest superphosphate and ground phosphorite; among limestone fertilizers: ground limestone, marl and ground dolomite.

The following fertilizer dosages per ha. may serve as models, *their choice depending on the specific conditions and possibilities of the farm*: 1.5-3 tons of organic fertilizer (humus, rotten manure or peat suitable for fertilizing); 2-3 centners of superphosphate or 3-4 centners of ground phosphorite, or preferably 0.5-1 centners of superphosphate plus 2-3 centners of ground phosphorite; limestone fertilizer —3-5 centners.

If there is no limestone fertilizer on the farm and none can be procured before the sowing, organic fertilizer mixed only with phosphoric fertilizer may be used. If, on the contrary, there is no phosphoric fertilizer on the farm but there are lime ones or the latter can be procured before the sowing, the organic fertilizer must be mixed with the limestone fertilizer.

The measures we have devised amount essentially to the creation of conditions favourable for the vital activity of the micro-organisms of the soil. The products of the vital activity of these organisms, which inhabit the young root zones, are essential for normal plant nutrition. The mixtures we recommend of organic and mineral phosphoric and limestone fertilizers are needed as food for the micro-organisms living in the zones of the young roots of agricultural plants. In podzol and particularly acidic soils these micro-organisms do not find adequate food and other conditions

for their development. In consequence plants growing on such soils starve: on the one hand, because there is a lack of the products of the vital activity of micro-organisms living in the root zones and constituting essential elements of the complex of root nutrition of the plants; on the other hand, because some of the products of the vital activity of root micro-organisms are essential nutritive elements for micro-organisms existing outside of the root zone and transforming by their enzymic activity forms of matter unassimilable by roots into assimilable forms.

This explains why the fertilizer mixture we suggest must be applied not a long time before sowing, but about 1-5 days before the pre-sowing soil cultivation, and must be introduced into the soil not at a depth of 15-20 cm., but at that of the seed-bed, i.e., at the depth at which the soil of the pre-sowing cultivation becomes friable.

In brief, *the proposed measures aim at receiving good crops on sections of low fertility and at converting low-fertility soils into high-fertility soils by means of good crops, particularly of perennial grasses.*

The theoretical principles of the developing Michurinist biology and the results of the experiments performed by the Lenin Academy of Agricultural Sciences of the U.S.S.R. by a consensus of opinion have predicted a great future for the proposed method of applying fertilizers, particularly on podzol soils.

The mixing of fertilizers and their even spread over the fields before the pre-sowing cultivation can easily be mechanized. Samples of such machines are already available. Manure and mineral-fertilizer spreader TUR-7 makes a good job of mixing organic with mineral fertilizers and spreading them over the fields. With this machine and a loader, 3 people can easily mix and spread enough fertilizer in one day for 10-15 ha., at the rate of 3-5 tons per ha.

The main thing is to convince agronomists and collective farmers by their own experience that the introduction before sowing at seed-bed depth of small doses of organic fertilizer

enriched by mineral phosphoric and limestone fertilizers is on podzol soils several times as effective as when the same fertilizers are applied separately, or at different periods or depths. So long as the different localities have no machines for mixing and spreading, these operations will have to be performed by hand. The mixing may be done with shovels and the spreading with the aid of lorries or carts moving across the field. The fertilizer should be covered up by pre-sowing cultivation or disking.

I have already stated that if a particular collective or state farm has no humus, peat suitable for fertilization may be taken for mixing with phosphoric and limestone mineral fertilizers. Before peat can be used to prepare a mineral fertilizer mixture it must be drenched with liquid manure, which introduces into the peat the necessary microbic ferment. Peat may be mixed with rotten manure. In that case the liquid manure may be dispensed with.

Agronomists, collective farmers and state-farm workers in the non-chernozem belt displayed great interest in the Lenin Academy's fertilization scheme.

Unfortunately, the Ministries of Agriculture and of Agricultural Stocks of the U.S.S.R. during the winter grain sowing in 1953 did not afford the requisite assistance to the collective and state farms. They failed to supply them with limestone and phosphoric fertilizers, and likewise did not provide adequate organizational aid for carrying out this important measure.

It is necessary that as early as in the spring of 1954, both in the scientific research network and in the collective and state farms, extensive experimentation for production purposes should be instituted, whereby mixtures of organic with mineral phosphoric and limestone fertilizers should be applied to spring crops and to various agricultural plants, as well as to fruit and berry plantations. These fertilizer mixtures should, beginning with the spring of 1954, be used on a particularly wide scale in the square-pocket sowing of potatoes and vegetables.

Advanced collective farmers are already applying locally organic fertilizers mixed with mineral phosphoric fertilizers in the square-pocket sowing of potatoes and vegetables, and the results have been good. Organic fertilizers should also be mixed with limestone fertilizers.

The Academy's 1953 experiments showed that a fertilizer mixture composed of 3-7 tons of rotten manure or peat plus 2-3 centners of superphosphate and 3 centners of limestone material per ha. introduced into the pockets in the square-pocket planting of potatoes or into the planting furrow in row planting, results in a considerable increase in the potato yield.

Similar good results are obtained in experiments with such vegetables as cucumbers, cabbage, etc.

In the square-pocket sowing of cucumbers and the planting of cabbage and tomato seedlings, at least 200-300 grammes of the fertilizer mixture indicated must be introduced into every sowing and planting pocket. This will raise the crop yield no less than the use of 40 tons of manure per ha. right before ploughing.

Very good results follow the planting of vegetables (tomatoes, cabbage and cucumbers) in earthen peat-and-humus pots, not only because plants in such pots do not suffer when transplanted into the field but also because in these pots there is nutrition for the development and vital activity of the micro-organisms that are the principal link in the soil nutrition of plants.

There are grounds for assuming that the application of organic fertilizers mixed with mineral phosphoric and limestone fertilizers will be the best means of fertilizing citrus plants in the subtropical districts of the Georgian Soviet Socialist Republic.

Proper nutrition of citrus plants will be one of the measures used in combating the *mal secco* disease in lemon plantations. In this sphere Comrade Shanidze (Batumi Botanical Gardens) has achieved promising results.

No more than 5-10 kg. of a mixture of organic fertilizer

with mineral phosphoric and limestone fertilizer need be introduced under each citrus or other fruit tree. It is best to introduce it under every tree in nests (3-5 holes 10-20 cm. deep).

In the Soviet Union the mineral fertilizer supply to the fields was improving each year. Now the decision of the September 1953 Plenary Session of the Central Committee of the Communist Party of the Soviet Union envisages an increase in output of mineral fertilizer and limestone material equal to several times the former output in order to provide for the country's agricultural needs. It is further contemplated to increase sharply the production and accumulation of organic fertilizers: manure, peat, peat compost and peat-and-manure compost. Soviet agriculture will be receiving huge quantities of various machines required for its organic and mineral fertilizer programme.

This gives rise to an unprecedented demand for more and more rational methods of using fertilizer so as to enlarge crop yields in all the fields of our country. At the same time it opens up new and wide avenues for the development of soil biology, the science treating of the soil nutrition of plants (the fertilization of fields).

The decision of the September Plenary Session points out that many scientific research institutes and experiment stations carry on their work divorced from practice, lock themselves up in their laboratories, keep aloof in their experimental fields, and fail therefore to enrich science and practice with new discoveries and proposals. They are thus of little help to the collective farms, machine-and-tractor stations and the state farms in improving methods of tillage and animal husbandry. The fundamental principle enabling science to develop—unity of theory and practice—has been violated. Deep theoretical problems of the development of living nature must always be solved with an eye to the settlement of practically important issues, making use of the unprecedented possibilities created by the Party and the Government for the development of science. Science

cannot develop with any success without daily propaganda and the penetration of the achievements of science and of advanced scientific experience into the sphere of production. The Plenary Session raises this issue alongside other important issues that must be decided so as to be able to cope with the problem of bringing about a steep rise in the level of agriculture in our country. The Academy and its institutes, and the workers of the entire network of agricultural research must revise the programme of their work in the light of the decisions of the Plenary Session. When fulfilling practically important tasks of collective- and state-farm plant-growing and animal husbandry, we still do not make adequate use of the achievements of theoretical Michurinist biology. This hampers the further development of the theory of Michurinist biology.

Workers in the field of agricultural science in close unity with the foremost representatives of collective- and state-farm production must put an end to the lagging of the science of agriculture behind the steadily mounting demand for increased production. We are fully able to do so. There can be no doubt that the scientific workers in agriculture will make use of that tried and true means of eliminating shortcomings in work—criticism and self-criticism, and that the science of agriculture will take its proper place in implementing the decisions of the September Plenary Session concerning the new powerful advance of agriculture in our country.

SOME URGENT PROBLEMS OF THE ADVANCE IN GRAIN AND ANIMAL HUSBANDRY

I*

The entire Soviet people accepted the decision of the September Plenary Session of the Central Committee of the Communist Party of the Soviet Union, on the report of N. S. Khrushchov and the decisions of the Government implementing the instructions of the Plenary Session as a militant programme of work to effect a rapid and decided advance in socialist agriculture.

The important part played by agricultural science in the development of production on our collective and state farms is widely known. But while its achievements are far from small, the science of agriculture in our country is still unable to cope with the tasks it must face and helps production less than it could and should.

The scientists engaged in biological and agricultural work must coordinate their activities more closely with agricultural production, must deepen their knowledge of the biological laws of development of plants, animals and micro-organisms.

The scientific truth of Michurinist agrobiology, its power and effectiveness, are to be explained solely by the fact that they have developed in intimate contact with practice.

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* From an address delivered on January 26, 1954 at the All-Union Conference of Machine-and-Tractor Station Workers, called by the C.C., C.P.S.U. and the Council of Ministers of the U.S.S.R.

The more the scientific workers strengthen this unity and the greater the number of agronomists and advanced workers in production who will join in the effort to solve theoretically and at the same time practically important problems, the faster will be the pace of development of the science of agriculture and the more substantial will be the assistance rendered by it to collective- and state-farm production.

When speaking of increased yields—of food, industrial and fodder crops—fertilization is of the utmost importance. This is not a new problem. It is as old as farming itself.

I am firmly convinced, however, that the question of fertilizing soils and, consequently, of the soil nutrition of plants, is dealt with by one of the most backward departments of agricultural science. Feeding plants from the soil —precisely the purpose of fertilizing fields—is, like the feeding of animal organisms, a biological process, and biology must discover its laws.

Agrochemists have done much to ascertain the specific chemical qualities of soils, the chemical composition of various plants and their separate organs, and the chemical composition of the nutrients needed by plants. These are all achievements of agrochemistry, but agrobiology has not discovered to this day the biological laws governing the soil nutrition of plants. Yet the slightest scientific achievement in this sphere may prove of great assistance to agricultural practice with regard to field fertilization, to crop-yield increases.

Indeed, no sooner had our Michurinist biology approached the problem of the soil nutrition of plants as a biological process and revealed its most general laws than ways and means were found of considerably augmenting the effectiveness of organic and mineral fertilizers—phosphoric and limestone—introduced into the soil. I have in mind the application of mixtures of organic fertilizers with mineral phosphoric and limestone fertilizers for podzol

soils, soils with high acidity and containing little organic matter.

The great amount of factual material accumulated by experimental institutions and also by pioneer practitioners of collective and state farms warrants the assertion that the application of mixtures of organic with mineral (phosphoric) and limestone fertilizers on acidic podzol soils planted to any crop, especially winter wheat and rye, or vegetables and potatoes, is of extreme importance in enhancing yields.

The effectiveness of these fertilizers when mixed, as compared with their use separately, or at improper depths or times, is multiplied no less than 3- or 4-fold. In actual fact, 2-4 tons per ha. of humus or rotten manure, of peat and manure compost or even of simple peat, if mixed with 0.5 centner of superphosphate and 2-3 centners of ground phosphorite and 3-5 centners of limestone material, applied before sowing and covered up by the pre-sowing cultivation of winter-wheat crops, produce the same effect as 20-30 and even 40 tons of good manure introduced into a fallow sector, even if the regular or even a higher dose of phosphoric fertilizer had been administered to the given crop, but separately, not mixed with manure.

The same result is obtained if a handful (200-300 gm.) of the said fertilizer mixture is put in each hill or pocket on sowing or planting vegetables, potatoes and other row crops.

We must take all measures necessary to carry out the decisions of the September Plenary Session of the C.C., C.P.S.U. as regards the increased accumulation and thrifty use on the collective and state farms of organic fertilizers, such as manure, peat and peat-and-manure composts. According to the Plenum decision, the chemical industry is increasing the output of mineral fertilizer several times over. This includes phosphoric fertilizer—superphosphate and ground phosphorite. Where the soil is acidic—and there are many millions of hectares of such land—the procurement and ap-

plication of limestone materials must be increased to an amount many times superior to the present figure.

Besides, the collective and state farms, together with the staffs engaged in Michurinist agronomic biology, have achieved considerably greater fertilizer efficiency and thereby made possible considerably lower per-hectare fertilizer consumption standards—instead of 20-40 tons of organic fertilizer per ha. only 2-4 tons and instead of 3-6 tons of limestone material only 3-5 centners. They have greatly spread the use of ground phosphorite by enhancing its effectiveness, and likewise have mechanized the mixing and spreading of fertilizer. In the next few years they will be able to fertilize annually not merely the former 10-15 or at best 20 per cent of the aggregate sown area of the collective- and state-farm fields, but the whole 100 per cent of that area, comprising fields under food, industrial and fodder crops, and even part of the hay lands.

The main thing now is to convince the agronomists, agricultural workers, collective-farm chairmen and collective farmers of the supreme expediency of using the fertilizer mixtures suggested.

It is to be regretted that last autumn only a small quantity of the above fertilizer mixtures was applied to the winter crops for experimental and productional verification on the collective and state farms. But at any rate the mixture was used on 30,000 to 35,000 ha. of collective-farm land with podzol soil. Thus, on the initiative of the Regional Agricultural Administration, proper experiments have been carried out on the collective and state farms of Gorky Region. Already in the autumn, before the plants began to winter, quite favourable results could easily be observed. It is highly desirable that the experiments begun in the collective and state farms, as well as in the scientific research network of various regions, should be utilized on the broadest scale to convince people by actual demonstration of the expediency of applying this highly important measure on millions of hectares already in 1954.

Our agricultural agencies must see to it that limestone materials are procured and delivered to the collective farms in time. It is necessary for collective and state farms to have each year at least 3 centners of limestone material, 2-3 centners of ground phosphorite or 1-2 centners of superphosphate per ha. of podzolic soil.

We have to increase as much as possible (to double or treble) the amount of manure to be got ready, must multiply many times over the winning and delivery of peat, must accelerate its output and the supply of TUR-7 machines to machine-and-tractor stations, as their performance has been shown by experiments to be good. With a crew of two and a loader this machine can daily mix, transport 5-10 km., and spread this fertilizer mixture over a surface of about 15 ha.

In the spring of 1954 the above mixture must be applied as extensively as possible, inserting at least 200-300 gm. into each pocket or hill when sowing or planting vegetables, potatoes, industrial and other row crops, and also when fertilizing fruit-trees and berry bushes. Each tree requires 5-10 kg. of the mixture—1-2 kg. per hole of 10-20 cm. in depth, all holes being placed at a distance from the tree trunk about equal to the radius of the crown. Under berry bushes 3-5 kg. of the mixture should be put.

When planting potatoes with four-row square-pocket planters, which can introduce into the pocket only simple granulated superphosphate (not mixed with an organic fertilizer), it is advisable, in districts where potatoes require hilling during the vegetative period, for collective and state farms to spread a mixture of organic and phosphoric fertilizers over the fields before the machine-planting and not to cover it up. Both during the planting and the later hilling of the potatoes, this whole fertilizer mixture will be shifted together with the upper layer of the soil by the hilling implements from between the rows and will get under the bushes.

We know that the progressive character of square sowing and the square-pocket sowing and planting of row crops

can be summarized by describing it as a method which, if correctly applied, cuts labour and makes the work of cultivating row crops easier. Besides, the soil is tilled better during the vegetation of the plants. That explains why a bigger crop is obtained.

In our country the square and square-pocket sowing or planting of row crops was first applied in the advanced collective and state farms. As early as 1949 an area in the Ukraine amounting to over 1.5 millions of hectares was sown to maize on these farms by the square-pocket method with very good results.

The proper employment of square and square-pocket sowing and planting creates the conditions required by the biological laws of life and development of agricultural row crops.

Darwin and Darwinism revealed the law of life of species, according to which all processes going on in an organism, as well as all interconnections with like organisms, i.e., within the species, are, in spite of all the diversity of these processes, directed (except for pathological, morbid phenomena) towards one end—the prosperity of the species, its numerical increase.

This law of life of species, discovered, as I just stated, by Darwin, is utterly at variance with the erroneous, reactionary scheme worked out by Malthus and mistakenly accepted by Darwin which speaks of intraspecific overpopulation and a resultant intraspecific struggle and competition. Hence our Michurinist teaching long ago cast aside in biology the mistaken Malthusian scheme, and does not recognize any such non-existent intraspecific overpopulation in nature nor any struggle or competition between the individual members of a species allegedly resulting from the latter.

Speaking from this eminent rostrum I want to say that the few of our biologists who to this day maintain the wrong Weismannist proposition that there is intraspecific overpopulation in living nature and hence also intraspecific

struggle and competition, are, whether they want to or not, theoretical opponents of the application in practice of hill sowing or pocket planting of row crops.

As they understand it, the plants composing any species compete, struggle, keep down one another as they grow jointly, and do so not less but even more than plants of different species.

Or, to put it otherwise, plants of the same species—maize, for instance, or any other species—keep down one another as much or even more than they are kept down by weeds growing together with them and belonging to other species.

And yet everybody knows that this is not so, neither in free nature nor in farming practice. Weeds are the worst enemies of cultivated plants, and the fact is not that cultivated plants keep down one another, for instance maize going against maize, but that weeds keep down cultivated plants.

Under the square-pocket sowing and planting system, if correctly applied, plants of the same species do not oppress one another, do not compete with one another. Their mutual relations tend to multiply the members of the species under the given conditions, to increase the crop under the given conditions. Therefore there is a great future in store for the correct application of square-pocket sowing and planting of row crops.

Recently a conference was held at the Lenin Agricultural Academy of the U.S.S.R. It was devoted to the cultivation of virgin and long-fallow lands in certain districts of Siberia, the Urals and North Kazakhstan. In putting virgin and long-fallow land to the plough, and in general when ploughing land, including plots sown to perennial grasses, the main thing is that the ploughing should be done right. If the surface soil gets mixed with the organic refuse lying at the top of virgin soil, the crop obtained after such ploughing will not be good, even if precipitation is adequate. But if this organic refuse is placed by a plough with a skim coulter at the bottom of the furrow and covered with a layer of

plough land, the crop will be a good one, and if precipitation is adequate, even a very good one. If the land was not ploughed right, if the soil got mixed with cellulose, the crop will be bad not only the first year but also the second. Even the third year it will be only slightly better. That is the point that requires attention. It depends exclusively on the machine-and-tractor station workers.

On behalf of the workers in agricultural science, I can assure our Party and its Central Committee, our Soviet Government and all of you who have gathered here that we shall make more extensive use of the tested weapon of criticism and self-criticism in order to eliminate the shortcomings in our work, and shall discharge our duty to our country by rendering every assistance to this new powerful advance of socialist agriculture.

II*

We all know how much the productivity of milch-cow herds depends on how they are fed and cared for. Nevertheless I shall intrude upon your time to call your attention to these problems and tell you how milk yields may be tremendously increased by improving the nutrition of milch cattle.

Until 1947 the dairy department of the Academy's Gorki Leninskiye experimental farm near Moscow devoted almost no time whatever to the milch-cattle problem. The department had its existence, fed its cattle well enough, and attained an average milk yield of 1,987 kg. per forage-fed cow. In 1948 we began to tackle this job in earnest. I shall not dwell on the subject at length but shall confine myself to figures.

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* From an address delivered on February 4, 1954 at the All-Union Conference of State-Farm Workers called by the C.C., C.P.S.U. and the Council of Ministers of the U.S.S.R.

The milk yield per forage-fed cow on the Gorki Leninskiye dairy farm was as follows:

1947	1,987 kg.
1948	4,100 »
1949	5,168 »
1950	5,320 »
1951	5,243 »
1952	6,135 »
1953	6,580 »

It must be taken into account that in 1953, 60 per cent of the cow herd had calved only once or twice.

That's how the milk yield can be raised by good feeding!

By the way, everybody is familiar with this problem and perhaps it is not worth while speaking about. But the proper feeding of cattle requires much fodder and a variety of fodder, and a large amount of fodder in great variety requires good harvests of all crops—both cereal, fodder and root crops. In this, I believe, you will agree with me. Then everything will be in abundance—grain, meat and milk. This too is common knowledge.

And what is needed to get good crops of all cultivated plants? That the fields should be well tilled and the plants well nurtured, i.e., that the fields should be fertilized.

Many, perhaps all of us here, are likewise aware of the fact that all kinds of field work—ploughing, harrowing, cultivation, rolling—is done to improve conditions for the soil nutrition of plants. But how plants obtain nutrition from the soil is something which, I dare say, few people know even now.

For centuries people have known that manure is the best of fertilizers. That is so and will remain so for hundreds of years to come. But people also know that plants do not feed on manure, although, as has already been said, we all realize that after the soil has been manured all cultivated crops thrive.

The root nutrition, which means the soil nutrition, of plants is to this day the most unexplored problem of biology. At the same time it is the main problem. Without proper root, i.e., soil, nutrition of plants it is difficult to increase crop yields.

The process of the soil nutrition of plants—the process of the alimentation of plants through their roots—is a biological process. Once this is so, it goes on on the basis of biological laws. And if biological laws are its basis, these laws must be discovered and it will then be plain how to create the best conditions for the soil nutrition of plants in any particular case.

Hitherto it has been held, though incorrectly, that the soil nutrition of plants was governed by chemical laws. For some reason or other biologists and agronomists have been of the opinion that only agrochemists should engage in the science of the fertilization of fields, i.e., of the alimentation of plants.

It must be acknowledged that agrochemists have done much useful work for agriculture. They have been investigating and will continue to investigate the chemistry of the soil, the chemistry of fertilizers, the chemistry of plant nutrients, the chemistry of plants. But the process itself of the nutrition of plants, as well as the process of the nutrition of animals, is a biological process. It would never occur to anyone that the physiological laws of the nutrition of animals should be discovered by chemists. Yet in agronomic science it was considered hitherto that it behooved chemists to discover the laws of the soil nutrition of plants. Agronomists and biologists kept aloof. This was wrong. And there was no reason to complain against the agrochemists on account of their failure to discover these laws. It is not their speciality.

It is the biologist-agronomists' business to discover the laws of biology and that is the reason why in our country Michurinist biology has tackled this problem. And no sooner had the problem of the soil nutrition of plants been

approached from the biological angle and at least the most general laws of the alimentation of plants from the soil been discovered than it became possible to give useful advice to practical agriculturists on that basis. Today it may be said with certainty that if the soil nutrition of plants is treated as a problem of biology, fertilizers—both organic and mineral—become from 3 to 5 and in some cases even ten times as efficacious as before.

The interconnection between the root systems of all plant species and the species of soil micro-organisms specific for each plant species or group of related plant species has been ascertained. The root nutrition of plants takes place through the agency of the corresponding soil microflora. Without a corresponding soil microflora plants cannot normally obtain food from the soil. The whole of agrotechnics (the ploughing, cultivation, harrowing, rolling and fertilization of fields) serves the purpose of creating the conditions necessary to improve the vital activity of soil micro-organisms beneficial for the plant species in question.

It may be said that the appropriate soil micro-organisms fulfil the same functions for the root nutrition of plants as does the digestive system for the nutrition of animals. Foods animals need to exist enter their digestive system in forms unsuitable for direct assimilation by their organs, the tissues of their organisms. Foods acquire assimilable forms only under the influence of gland secretions—juices produced by the digestive organs.

Soil micro-organisms play the same role in the root nutrition of plant organisms as the digestive system in the nutrition of animal organisms. The significance of these micro-organisms in the structure of the organic plant world is colossal. By establishing the conditions for the normal vital activity of the micro-organisms (soil microflora) we create the conditions that soil fertility demands. There are cases when the soil lacks only a few of the factors which bring about a normal vital activity of the micro-organisms that are beneficial to agricultural plants and hence also

spell great soil fertility. As soon as this deficiency is eliminated we shall have sharply improved conditions.

Let us now take a concrete example to see what practical advantage can be derived from a correct understanding of the biological laws of the root nutrition of plants. When fallow land is prepared for winter wheat or rye on podzol soil, 30-40 tons of manure per ha. have usually to be applied. It has now been proved that if we take 2-3 tons of manure or humus (or even peat if drenched with liquid manure), add first 3-5 centners of limestone materials and then 2-3 centners of ground phosphorite, and introduce this mixture into the soil 1-2 or 3-4 or at most 7 days before sowing the winter crop at seed-bed depth, i.e., cover up the fertilizer by pre-sowing cultivation, we get the same crop as from 30-40 tons of good manure applied on bare fallow. This reduces the organic fertilizer dosage to one tenth, which makes it possible to fertilize an area ten times as great. Thus the time is brought near when all crops on all sown areas in our country will be given good fertilizer and will yield big crops.

Why the requirement to mix organic fertilizer with lime and phosphoric fertilizer? Why must this mixture be worked in at a small depth and shortly before sowing or planting fruit trees, before planting potatoes or cabbage? These questions are fully answered in a special booklet.*

The explanation is briefly as follows: Once root nutrition takes place through the agency of soil micro-organisms it becomes necessary to ensure normal conditions for their vital activity, ensure food to those micro-organisms which exist near or on the roots of the plants. This end is served by a not too deep application of fertilizer. Why must the fertilizer be absolutely applied in the form of a mixture? For the reason that if immediately before the sowing organic matter rich in cellulose, for instance, peat or straw

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* See the article entitled "Soil Nutrition of Plants and Increased Agricultural Crop Yields," p. 5 of the present collection.—*Ed.*

or even too strawy manure, is introduced by itself without phosphorus or lime, wheat for instance will experience a shortage of nitrogen. Many of you know what it means to plough a lot of straw not too deep into the soil before sowing. This soil will not yield a normal crop, for so-called denitrification will take place. In decomposing the straw the cellulose bacteria eat up the nitrogen nutrient. It is this that constitutes the process of depleting the soil of the nitrogenous food to be assimilated by the plant.

And what will happen if lime and phosphorus are applied together with these same organic substances, i.e., cellulose? The cellulose bacteria will attack the cellulose and make off with the nitrogen in the soil. The cellulose is assimilated, the enzymes convert the cellulose into sugar and sugar appears in the soil. So the soil now has phosphorus, which was introduced, has lime, and has sugar that was converted from the cellulose by the cellulose bacteria. And once the soil contains phosphorus, lime, sugar and air, energetic vital activity will inevitably develop on the part of the bacteria of other species which fix nitrogen from the air—the azotobacteria. With the aid of glucose, phosphorus and lime these bacteria change the nitrogen of the air into ammonia nitrogen and organic nitrogen.

By creating in the soil the proper conditions for the vital activity of the micro-organisms, we transform, as it were, in the case under discussion, the cellulose (straw) into nitrogenous food for the plants. Take a look at wheat fertilized in this manner and you will see that it has the appearance of having been treated with a mineral nitrogen fertilizer. The plants are well developed, dark green in colour. Now if the soil contains nothing but cellulose, and no phosphorus or lime, the nitrogen-fixing bacteria will not develop their vital activity, will not feed the plant with atmospheric nitrogen.

That is why it is so important that the fertilizer be a mixture.

I shall not go into details now, but dwell only on one component of the mixture—the limestone materials.

What does experience teach us, particularly the experience gained with podzol soils?

Let me recall some figures relating to last year's Gorki Leninskiye experiments, with which some of you may be acquainted. Winter wheat, sown in the autumn of 1952 after an unfallowed preceding crop on strongly acidic podzol soil without any fertilizer, produced 17.8 centners per ha. Into other plots 1.8 tons of humus with an admixture of 3 centners of superphosphate and 3 centners of ground limestone were introduced. The crop obtained was 28.7 centners per ha. Is it possible that the superphosphate had this effect?

No. Not at all. The plots in which 3 centners of superphosphate per ha. were put, but in a pure form, not mixed with humus or lime, yielded only 22 centners per ha.

Now the last and most interesting point: From the plots into which 1.8 tons of humus plus 3 centners of lime without an addition of superphosphate had been introduced, the crop yield was 27.3 centners per ha., and the application of 50 centners of lime alone produced a crop of 22.6 centners per ha. I shall not impose on your patience by citing additional examples. I only wish to add that this is not the only experiment of this kind. On tens of thousands of hectares the influence of fertilizer mixtures has been tested and the high effectiveness of this method of applying them has been proved.

But where is one to get the limestone material to be introduced annually at the rate of 3-5 centners per ha. into podzol soil, mixing this limestone material with 2-3 tons of organic fertilizer?

Our country has many lime deposits. They are found in the non-chernozem zone and elsewhere. The September Plenary Session of the Central Committee of the Communist Party of the Soviet Union devoted much attention to the procurement of lime. Its price has been lowered. The Govern-

ment has been taking all necessary measures to increase mineral fertilizer output considerably. But the lime fertilizer supply is still insufficient, or, to be more exact, it is almost non-existent in the storehouses. Yet we are in extreme need of this fertilizer to increase crop yields, especially in the non-chernozem zone.

How can the state and collective farms be put in possession of limestone materials? Scientific workers in the Ministry of the Chemical Industry informed me that at Shchigri, Kursk Region, where phosphate rock is mined to prepare ground phosphorite, tens of millions of tons of chalk are lying about as so much waste material when phosphorite mines are opened. This chalk is a soft rock, i.e., it is readily fragmented. It contains an admixture of phosphorite, which suits our purpose very well. At any rate, this chalk is one of the best limestone fertilizers. Lastly, a railway reaches its deposits to haul the phosphorite. As this mineral is mined there, I believe loading and unloading are already mechanized. One might think all one has to do is to order a shipment of limestone fertilizer and it would straightway be delivered to the station nearest to the purchasing farm. Nothing of the kind. The delivery of this gratuitous limestone fertilizer must be organized, as it is exceedingly important for increasing crop yields.

Must lime material be brought from Shchigri or should it be taken from deposits nearer to the farms that need it? I am not sure I can settle this question now. But I maintain that our fields are badly in need of lime. It would therefore be the right thing, I believe, going by what is most expedient, to supply farms with limestone material from various deposits.

If every state and collective farm in the podzol zone could get limestone material this year, before spring, and prepare from it a mixture of 3 centners of lime and at least 1-2 centners of phosphoric fertilizer with 2-3 tons of humus or peat per ha. and spread this mixture in spring over winter wheat or rye crops, the yield would experience an increase

of 5-7 centners per ha. It would of course be better if this fertilizer were introduced in the autumn, when sowing, but now that this opportunity has been missed it can be introduced in the spring. There have already been such experiments.

Now I shall deal briefly with another important problem, that of developing virgin and long-fallow lands and of stretches of grass lands in various Siberian, North Kazakhstan, Urals and Transural districts in order to extend the area sown to wheat. Incidentally, this question is closely interlinked with everything I have said—the root nutrition of plants.

Undoubtedly there are people among you whose practical experience has taught them that once you plough virgin or long-fallow soil or land sown to grasses, particularly cereal grasses, incorrectly, you will never get a good wheat crop the first year (or even the following years). And what is meant by ploughing incorrectly? That means mixing not yet decomposed organic remainders, i.e., cellulose lying at the surface or in the uppermost layers of the soil, with the ploughed horizon. After such ploughing the yield will be 10-15 centners per ha. at the most and in droughty years a bare 5 centners, while 20-25 centners of wheat and more per ha. must be taken as normal from virgin soil. The size of crops on virgin land depends largely on the quality of ploughing. If the organic remainders of perennial cereal plants existing at the surface of virgin soil and in the uppermost layer of the soil are well ploughed in by a skim-coulter plough to the bottom of the furrow and covered on top by an adequate layer of soil in such a way that this soil will not mix with the organic remainders containing cellulose, the foundation of a good crop has been laid.

This conclusion is corroborated by the theoretical principles of Michurinist biology, the laws of the soil nutrition of plants discovered by Soviet science.

I adduce some experimental data obtained in Omsk Region in the fields of the Siberian Grain Institute of the

Lenin Academy of Agricultural Sciences in an experiment lasting two five-year periods on the ploughing of fallow land sown to perennial cereal grasses.

The first five years the ploughing and pre-sowing cultivation of the soil were done without a skim-coulter, and the inverted plough layer got mixed with the living and dead plant refuse found at the surface of the soil.

During the second five-year period the ploughing and pre-sowing cultivation of the soil was done correctly—by skim-coulter ploughs; the organic refuse was ploughed down to the bottom of the furrow and did not get mixed with the ploughed horizon.

In this experiment the following crops of durum spring wheat were obtained: an average during the first five years with wrong ploughing—9.1 centners per ha., and with right ploughing an average during the second five years of 13.1 centners per ha. This applies to summer ploughing. But in the case of wrong autumn ploughing, i.e., when the plant refuse was mixed with the ploughed horizon, the average crop during the five years was 6.1 centners per ha., with right ploughing that figure rose to 13.4 centners per ha.

And now some data on soft spring wheat Milturum 0321. With wrong summer ploughing the average crop for a five-year period was 10.3 centners per ha., and with right summer ploughing it rose to 15.8 centners per ha. With wrong autumn ploughing the yield was only 5.5 centners per ha., and with right autumn ploughing 16.4 centners per ha.

The above figures clearly show how important it is to plough virgin land correctly to get big crop yields.

I want to call your attention to one more point.

Even when the soil is ploughed correctly and the upper layer properly placed at the bottom of the furrow, yet if in spring the cultivators are set to work and the plant refuse of the undecomposed cellulose is pulled up from the bottom of the furrow to the surface and mixed with the soil, everything will be spoiled. Hence the pre-sowing cultivation must be done in such a way that the refuse worked down to the

bottom of the furrow by the skim-coulter plough will not be pulled up from under the ploughed horizon.

In conclusion I sincerely wish that the ties between the collective- and state-farm production workers and the Michurinist biological workers should become stronger and more extensive. The indestructible alliance between advanced Soviet science and advanced socialist agricultural practice will help to fulfil sooner and better the grand tasks imposed by the September Plenary Session of the Central Committee of the Communist Party of the Soviet Union in the effort to achieve a steep rise in socialist agricultural production.

SOIL NUTRITION OF PLANTS AND FERTILIZATION OF FIELDS*

Under the leadership of the Communist Party of the Soviet Union and the Soviet Government, the whole Soviet people is engaged in the battle for a steep rise in the level of its agriculture. Tens of thousands of Soviet patriots—mechanizers, agronomists and other workers in the field of agriculture—have gone to bring into cultivation the vast virgin spaces of Siberia and Kazakhstan. Fertilization and increased soil fertility play no small part in the solution of the foremost task set by the Party and the Government—a sharp increase in over-all harvest figures covering all agricultural crops. It is precisely to these problems that V. R. Williams devoted all his life. It was he who worked out the biological theory of the creation and development of soil fertility, an invaluable contribution to agronomics. To speak of field fertilization and the feeding of plants through the roots means to speak of soil fertility. That explains why I have chosen the problem of the soil nutrition of plants and the fertilization of fields as the subject of my address on V. R. Williams's Memorial Day.

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* From a paper read at a session of the Scientific Council of the Timiryazev Agricultural Academy in Moscow, dedicated to the fifteenth anniversary of Academician V. R. Williams' death (1939).

A number of us scientists working at the Lenin U.S.S.R. Academy of Agricultural Sciences have been devoting ourselves during the last few years mainly to the elaboration of the biological foundations of the soil nutrition of plants, to the discovery of the biological laws of the root alimentation of plants.

The more profoundly we know the biological laws of the soil nutrition of plants, the easier it will be to work out more rational methods of field fertilization for the purpose of raising agricultural crop yields with less energy and means.

A combination of the materialistic Michurinist theory of the life and development of the organic world with Williams's theory of the development of the soil fully enables us to discover the still undiscovered biological laws governing the root nutrition of plants.

The biological laws of the soil nutrition of plants were unknown hitherto in biological, and hence agronomic science. Moreover, many scientific workers were and still are of the opinion that by studying soil chemistry, the chemistry of the food of plants and the chemistry of the plants themselves, they are disclosing the biological laws of the soil nutrition of plants.

Everyone knows that the laws, the basis on which biological processes take place, are not chemical and not physical laws. Chemical laws constitute the foundation of chemical processes and physical laws the foundation of physical processes, and so forth. None of these phenomena in nature or in agricultural practice are delimited, but it does not follow from this that they do not exist objectively. There was a definite purpose in classifying the sciences into physics, chemistry, biology, etc., and scientists working in the realms of these sciences must discover the laws governing the various phenomena comprised in the subject-matter of their respective sciences.

Only a knowledge of the natural laws involved enables one consciously and confidently to take practical steps, to give

free rein to the manifestation of any parti- regularity in nature if it tends to be of use, -- to bar it from manifesting itself, if it tends to harm agricultu

However, not all scientists have as yet realized that to discover physical or chemical laws does not mean to discover the biological laws of the soil nutrition of plants.

A law of nature implies interconnections that necessarily follow from the essence of the phenomenon under analysis. If we want to elucidate the biological laws of the root nutrition of plants, we must find out the interconnections evolving from the essence of the phenomenon being studied, in the present case from the essence of the interconnections between a plant species and its conditions of life, between the plant's organs and its external environment. When it is a question of the roots, whose natural environment is the soil, the task is to discover the laws governing the interconnections between the roots and the soil.

I do not think you will find a single scientist who will seriously undertake to prove factually that there is any species of plant whose roots are not connected with specific soil micro-organisms by a necessity that springs from the very nature of these roots.

Although soil microbiology is still insufficiently developed, its practitioners have by now accumulated an appreciable number of facts confirming authentically that in natural normal soil nutrition of plants, their roots are closely connected with an appropriate soil microflora.

We know that all species of leguminous plants have nodule bacteria; moreover, almost all of them have bacteria of a specific kind. Thus, the nodule bacteria of clover will not live on the roots of lucerne; clover roots, in their turn, are unsuitable for the nodule bacteria of lucerne.

And this applies not only to legumes. Take the alder. It also has nodule bacteria. All ligneous species normally derive nourishment from the soil through the agency of specific bacterial or fungi (mycorhiza, the mycelia of fungi) appropriate for them, Numerous facts on the existence of

so-called soil rhizospheric micro-organisms have been accumulated by microbiologists.

The materialist conception of the interconnection and interdependence of phenomena in nature and the factual material accumulated by soil microbiology permit of the assertion that plants feed on the soil through the agency of suitable soil micro-organisms. The chemical elements of the bedrock, marl, the chemical elements of the air, many complex organic substances in the soil—are all forms of substances that plants cannot assimilate, but they are transformed into other, soluble substances that plants can get at. These transformations take place with the assistance of enzymes which are secreted by various kinds of soil micro-organisms.

Even if one starts out from such general notions of the soil nutrition of plants it has proved quite possible to work out, verify and propagate successfully much more rational methods of soil fertilization.

Fertilizer efficiency may already be increased several times over. The effect on acidic podzol soils of low fertility is particularly great.

On soils of medium fertility the effect of particular fertilizer doses will of course be smaller, and soils of high fertility in a number of cases need no fertilizer at all.

It has long been known that in unfertile podzol soils, in Moscow Region, for instance, 20-40 tons of manure, or 50-100 tons of good peat instead of manure, must be applied per ha. to get 20-25 centners of winter wheat and more per ha. For ground phosphorite, the quantities recommended are 5-10 centners and even 1.5 tons per ha. When liming, 3-6 tons of limestone material such as ground limestone is introduced, depending on the degree of acidity and the composition of the soil. The fertilizing methods we have devised make it possible considerably to reduce the dosages of manure, mineral fertilizers and limestone materials without diminishing crop yields on such podzol soil.

Here are the 1954 experiment data on winter wheat

obtained on the experimental farm of the Lenin U.S.S.R. Academy of Agricultural Sciences at Gorki Leninskiye. On each of 3 different fields, each measuring about 20 ha., 3 ha. were set aside for experimentation. The size of each experimental plot was 500 square metres. Three sets of experiments were made. In the first set winter wheat was sown on unfertilized fallow acidic podzol; in the second set, it was sown after winter wheat; and in the third set, after vetch and oat mixtures in fields long under cultivation:

The experimental plots were fertilized with mixtures of organic, phosphoric and lime components applied in different compositions before the pre-sowing cultivation. Alongside each experimental plot lay a wholly unfertilized control plot.

The winter wheat sown on unfertilized fallow land proved worse than it did in other fields. This confirms once more that unfertilized fallow on podzol soil is not enriched in food for a succeeding wheat crop.

Let us cite the results of a small part of the experiments on fallow land:

Various fertilizer mixtures used	Winter wheat crops (in centners per ha.)	
	Experiment plot	Control plot
3 tons humus + 2 centners superphosphate + 3 centners ground limestone	22.1	13.7
Same mineral fertilizers but no humus	17.9	14.7
3 tons humus + 2 centners powdered phosphorite + 1 centner superphosphate	20.7	14.7
Same mineral fertilizers but no humus	17.6	11.4

As we see, the organic-phosphoric-limestone mixture considerably raised crop yields when compared to the control yield figures, i.e., to the unfertilized plots.

A handsome though smaller yield increase was achieved where superphosphate and ground phosphorite mixed with ground limestone but without humus, i.e., without organic fertilizer, was applied.

Some agrochemists violently oppose our biological conception of the soil nutrition of plants and the fertilization method we propose. They are particularly against mixing phosphoric fertilizers (superphosphates and ground phosphorite) with limestone materials. They believe that as the inevitable result of such mixtures the phosphorus of superphosphates, which is capable of assimilation by plant roots, forms compounds that cannot be assimilated, and unassimilable ground phosphorite cannot, where lime is present, assume an assimilable form due to the action of soil acids, i.e., in acidic soil.

Are they right in this question? From their point of view, that of chemists, they, of course, are. In a mixture of limestone materials with phosphoric fertilizers, soluble and hence plant-accessible phosphoric acid calcium salts with mono and dicalcium phosphates turn into tricalcium phosphate, which is not accessible. The truth of this can easily be established experimentally in a chemical laboratory.

But these agrochemists do not want to know that the process of the nutrition of plants does not go on on the basis of chemical but on that of biological laws, although all biological processes take place by means of chemical transformations. It is biological laws that form the basis of the interconnections between plant roots and the chain of specific soil micro-organisms. The enzymes secreted as a result of the vital activity of the microbes (they are secreted outside the microbe cell) act on the chemical compounds, which change from insoluble substances that cannot be assimilated by plants into soluble substances, into food that the roots of plants can absorb. Therefore, if you know the biological laws of the soil nutrition of plants, there is no reason to be afraid that the food reserves in the soil

will be in a form insoluble in water, i.e., in a form in which they cannot get into direct contact with the roots of the plants.

That phosphoric fertilizers (ground phosphorite) not soluble in water and hence inaccessible to plant roots can change into water-soluble compounds also in a non-acidic medium, i.e., not under the action of acids, can likewise be easily demonstrated under laboratory conditions, in Petri dishes. Thus, at my suggestion, the post-graduate student G. S. Muromtsev devised the following experiment. He prepared a food-medium from agar-agar for the soil rhizospheric micro-organisms of wheat. The reaction of the medium was not only not acidic but slightly alkaline. For this food-medium phosphorus in water-insoluble form (ground phosphorite) was used. After inoculating this medium by means of small lumps of soil from a field sown to winter wheat, the micro-organismal colonies developed well. The medium, turbid from the ground phosphorite, became transparent around the bacteria colonies, i.e., the ground phosphorite dissolved there. The said micro-organisms are also developing well in the Petri dishes in which chalk, i.e., limestone material, is added to the water-insoluble ground phosphorite. But in the dishes in which only chalk was added and no ground phosphorite was introduced, there was no microbe development. Consequently, in a non-acidic food medium, even if chalk is introduced into it, the phosphorus of the ground phosphorite will, due to the action of the enzymes secreted by the micro-organisms, turn from a non-soluble compound into a soluble one. It seems to me to be the duty of agrochemists to clarify this matter, to ascertain the chemical process involved here.

In addition to the data already given on the efficacy of mixtures of organic and phosphoric fertilizer with ground limestone, still other figures from the same field experiment will be of interest. They too indicate that the application of ground phosphorite mixed with limestone materials to acidic podzol soils does not worsen but improves the con-

ditions of plant nutrition, with resultant increases in yields. For instance, a plot of land fertilized with a per ha. mixture of 3 tons of humus and 3 centners of ground phosphorite with 3 centners of ground limestone yielded 12.4 centners, while the unfertilized control plot produced only 5 centners per ha.

The same mixture—3 centners of ground phosphorite and 3 centners of ground limestone but without any humus, without organic fertilizer—also yielded a much bigger crop, although the increase was less than in the preceding case. The addition was 5 centners per ha. in comparison with the unfertilized control plot.

In Academician A. A. Avakyan's experiments at Gorki Leninskiye, winter-wheat sprouts on plots fertilized with a mixture of ground phosphorite and ground limestone also developed considerably better than on the control plots, i.e., the unfertilized plots in the autumn of 1954.

I believe mention should also be made of an experiment many became acquainted with through my articles and speeches. In the autumn of 1952 a mixture of 1.8 tons of humus + 3 centners of ground limestone was applied to sown winter wheat. The following year the grain crop amounted to 27.3 centners per ha. from the fertilized and 17.8 centners from the unfertilized plot. And in 1954 that fertilized field produced 49.3 centners of clover hay per ha. and a very fine lot of hay that was. The control yield was 34 centners per ha. and the quality of the hay was considerably worse, containing a large admixture of dock and horse-tail. Included in the same experiment were also plots which in the autumn of 1952 had been given 5- and 10-ton lots of ground limestone per ha., without organic fertilizer. The winter-wheat yield was 22.6 centners per ha., i.e., almost 5 centners less than on the plots which got only 3 centners of limestone, but mixed with 1.8 tons of humus.

In 1954, 42.6 centners of good clover hay were harvested from these plots per ha., i.e., no more than in the variant in which the so-called small fertilizer dosage was introduced,

namely 3 centners of ground limestone mixed with 1.8 tons of humus.

The following facts concerning this experiment present no little interest. It appears that on the plots that received 5 or even 10 tons of ground limestone per ha., a favourable influence is nevertheless exerted, judging by sight, on the development of the clover, if the following year these plots are given a surface application of 3 centners of ground limestone mixed with 1.5 tons of organic fertilizer.

This signifies that it is to some extent bad management to introduce big doses of limestone materials into acidic podzol soils. It will be considerably more rational annually to fertilize acidic podzol soils, to whatever crop they are planted, with the requisite doses of limestone materials, mixing them without fail with organic fertilizer.

Indeed, instead of putting 5-10 tons of ground limestone into the soil per hectare, one could spread this quantity, if mixed with organic fertilizer, over an area 10-20 times as great and the yield increase would not be smaller but bigger.

We know that the introduction of various limestone materials without organic fertilizer into acidic podzol soils effects a considerable yield increase only in the case of clover, lucerne and other leguminous plants. But in the case of various cultivated plants no great yield increase is obtained by the direct liming of podzol acidic soil containing little organic matter, unless organic fertilizer is introduced. Plants like flax, potatoes and blue lupine even suffer and have worse yields from the above-mentioned large doses of lime. However, the application of only 3-5 centners of limestone materials, mixed in each case with at least 2-5 tons of organic fertilizer (the more organic fertilizer the better) even without phosphoric fertilizer, had a good effect on all crops that were tested in the fields of the Academy of Agriculture's experimental farm. Herein included were such crops as potatoes and flax.

Let us cite the experiment performed by Academician

A. A. Avakyan at Gorki Leninskiye in 1954 relating to the action of organic-phosphoric-limestone mixtures, not on winter wheat, but on a number of other field and vegetable crops. A plot with acidic podzol soil of low fertility was selected for this experiment. The per-hectare fertilizers used were 4-6 tons of decomposed manure mixed with 2 centners of superphosphate and 3 centners of ground limestone. As said above, this was a fertilization test on various field and vegetable crops. The effectiveness of the fertilizers used was good for all crops except blue lupine. The fact that in this experiment the fertilizer lacked efficacy with regard to blue lupine does not contradict, but on the contrary confirms our idea that the soil nutrition of plants proceeds through the agency of appropriate soil micro-organisms. The causes of the inefficacy of the fertilizer on blue lupine will be explained below.

I shall now quote a few figures on the application in this experiment of organic-phosphoric-limestone mixtures.

Beans on unfertilized plots yielded 6.9 kg. of ripe seeds a plot; on fertilized plots, 9.2 kg.; some other variety of beans yielded 4.5 kg. a plot without fertilization and 7.4 kg. with fertilization.

The maize hybrid VIR-42 produced on unfertilized plots an average of 14.1 tons of green silage per ha.; on fertilized plots, 23.4 tons.

Cabbage of the Slava variety, with sprouts planted 70×70 cm., grown without peat-compost pots, yielded an average of 113 centners per ha. without fertilizer; with fertilizer, 296 centners.

Sunflower plants produced without fertilizer an average of 15.1 tons of green silage per ha.; with fertilizer, 21.2 tons.

Of special interest are the results obtained with cucumbers. On the above acidulous section of low fertility cucumbers got along badly without fertilizer. One unfertilized plot yielded 2 tons of cucumbers per ha., another 1.7 tons. Nor did the yield increase when ground limestone was put into the seed holes. Putting in superphosphate slightly raised the

yield, to 4.7 tons per hectare. But this figure is also too low, as everybody will agree. When, however, they inserted an organic-phosphoric-limestone mixture, a cucumber yield of 20.9-25.6 tons per ha. was repeatedly obtained.

This cucumber experiment clearly shows that as far as cucumbers are concerned almost barren land can be made to produce a fairly good crop by the mere application of 4-6 tons of an organic-phosphoric-limestone mixture per ha.

I shall also cite the potato results obtained in the same experiment. Tubers of the Priekuli variety of the preceding year's summer planting were used. Every tuber was halved. One half was planted in a pocket without fertilizer, the other half in a pocket fertilized with the above mixture, in the neighbouring furrow. The crop was reaped separately from each pocket. In every single instance the tuber crop was 30-50 per cent bigger in the fertilized pockets.

In the case of all plants mentioned here (as well as in the case of other plants we do not speak of here), the fertilizer mixture was introduced into the seed holes. Of even greater interest are the buckwheat, flax and fodder-beet crop results achieved in this same experiment. Here the fertilizer mixture was not put into the rows or pockets with the seeds but was broadcasted, surface-sown and covered up by the cultivator.

In this experiment the buckwheat per-hectare yield without fertilizer was 9.5 centners of seed; with fertilizer, 13.9 centners; 2.8 centners of long-fibre flax seed were obtained without fertilizer and 4.2 centners with fertilizer; the average per-hectare production of fodder beetroots was only 20.8 centners without and 143.2 centners with fertilizer.

All the above data were obtained on an acidic podzol soil section of low fertility, as has already been stated.

For purposes of comparison I want to specify that approximately the same fertilizer doses given the same year (1954) not on a barren section for a crop like cucumbers but on the finest land in those parts, raised the cucumber yield on a 2-ha. patch of the Gorki Leninskiye farm to 55 tons per ha. Similarly fertilized, other sections of the farm

yielded the following crops, per ha: 347 centners of early cabbage, about 500 centners of maize silage, and over 400 centners of sugar beetroots.

Interesting results were obtained by broadcasting fertilizer to intertilled crops and in experiments conducted with the farm's crops by the agronomist F. V. Kalistratov of the Academy's experimental farm. He planted potatoes with an SKG-4 planter, a machine of new design, which can sow about 1.5 tons of organic-phosphoric-limestone mixture per ha. together with the potato tubers. Mineral fertilizer—potassium chloride and sulphate of ammonium—was given to the entire field. In the first section (11 ha.) the machine on planting the tubers introduced into the pockets a per-ha. mixture of 1.6 tons; in the second sector (0.3 ha.) no mixture was applied; in the third sector (6 ha.), in addition to the mixture introduced on planting by the machine into the pockets at the rate of 1.6 tons per ha., another 6 tons per ha. of the said mixture had been broadcast superficially before the planting. The organic mass consisted of a mixture of manure and peat.

The results obtained were as follows: Control plots (unfertilized) — 153 centners of tubers per ha. In the first section, where 1.6 tons of the mixture had been introduced per ha. into the pockets—211 centners per ha. In the third sector, where 1.6 tons of the mixture were introduced per ha. by the machine + 6 tons per ha. were broadcast—251 centners per ha.

This potato experiment goes to show that if it is impossible to insert the organic-phosphoric mixture into the pockets, potato fields can be given the organic-phosphoric-limestone mixture by broadcasting it in the spring of 1955, before the potato-planting machine starts its work. When the machine covers up the tubers and during the subsequent hilling the fertilizer together with the top layer of the soil is transferred to the potato plants and, as the experiment tells us, such fertilizer application has a good effect. Moreover, the outlay for the labour of broadcasting the fertilizer will be less.

Much additional experimental and factual data could be adduced, and not only from the Gorki Leninskiye records but also from collective-farm practice. Unfortunately, only a few Moscow Region collective farms performed such experiments with the 1954 crop. But in other regions of the non-chernozem belt thousands of hectares were actually fertilized in the manner indicated. The data obtained are similar to those I cited with regard to Gorki Leninskiye.

The Party and the Government always lend support to the progressive proposals of science and practice aimed at the development of agriculture. Owing to this assistance one may observe even now on nearly each collective farm of Moscow Region the results of the fertilization methods recommended by the Academy of Agricultural Sciences for the winter crops to be harvested in 1955. The effectiveness differs of course with different soils, but on the whole, judging by the development of the sprouts of winter wheat and rye, the effect obtained is good.

Today there are such crops in about one thousand of Moscow Region collective farms. Tens of thousands of people, agronomists and collective farmers, have done all this with their own hands, see all this with their own eyes, and therefore it may be said that success in this undertaking is a forgone conclusion. The only thing there is now to wish for is that this issue should be widely discussed and that the weak spots should be detected and eliminated.

It goes without saying that measures must be taken to ensure that in the spring of 1955, in the non-chernozem zone with podzol soil, the biggest area possible under vegetable, potato and cereal crops should be fertilized by this method. It is therefore of paramount importance that everything should be done to get the collective and state farms to accumulate and bring into the fields as much organic fertilizer (manure, peat-and-manure composts, good peat fit for fertilization) as possible, and also limestone materials in the acidic soil districts.

We have given some factual data concerning experiments in the application of the proposed fertilization method. But one should not confine oneself to these. After all, facts meant to go into a paper or article can be specially picked. We know that science cannot go on without facts. But facts by themselves, no matter how numerous, do not constitute science. Science is the generalization of factual material which, as a rule, is contradictory. If all data ran alike there would be nothing to generalize, to reveal. The whole thing would come down to a mere registration of facts: the results of the experiments are such and such. But why are they so? Nobody knows. But if the facts contradict one another the law involved must be discovered. Only upon discovery of the law, on generalizing what is contradictory, can one understand why in one case the yield rises and in another case it drops. Both increases and decreases in crop yields may, depending upon conditions, be consequent upon one and the same law. If you know the law you know how to act under any concrete conditions in order to increase yields.

* * *

The normal nutrition of plants from the soil goes on through the agency of the soil microflora appropriate for the particular species or for a group of related species of plants. By soil microflora one must understand not a single species of bacteria or fungi, but a chain of mutually interconnected species of soil micro-organisms—fungi, bacteria, etc. Should any species—a link in the chain of soil micro-organisms—be unable to find the conditions essential to its life, it dies off and the vital activity of the entire chain ceases because of the close interconnection of all its links.

The products of the vital activity of one species of microbes are essential to the existence of another group of microbes, and so forth all along the chain. For some species of micro-organisms dead organic substance is not essential to

life, for others it is. The microbiological chain we are analyzing originates from the roots of those plants which at the particular time grow in the soil. Their roots create suitable conditions for the development of micro-organisms peculiar to the roots of these species of plants. From this first link the whole mutually interconnected microbiological chain starts its development.

The enzymic activity of the micro-organisms is capable of transforming inorganic substances of the ground and air inaccessible to plants into accessible forms. For instance, rocky mountains are sometimes covered with huge pine forests. Where did the water-soluble nutrients for these trees come from? For stones are taken to be barren. They do not dissolve in water. But when acted on by the enzymes of micro-organisms, substances contained in these stones change into forms of food accessible to plants. In the case under discussion this is done by the micro-organisms in contact with pine roots.

From the biological conception of the soil nutrition of plants it definitely follows that the microbiological chain, by whose agency various plant species derive their food from the soil, is not alike for all plant species, and different species of micro-organisms require different conditions of life.

For example, some soil microbes contained in the chain which feeds wheat and other cultivated plants absolutely require organic matter for their existence. And you merely have to introduce into poor podzol soil a small dose of organic fertilizer together with phosphoric salts and limestone materials to have this link of micro-organisms form part of the chain, with the result that good yields of wheat and other agricultural plants may be obtained on podzol soil of low fertility. Why is an organic substance introduced into the soil? To mineralize it with the aid of micro-organisms, so that in this shape it may become accessible food to plants? That is so and yet not so.

If rotten manure that has turned into humus is spread

over a hot bed, the plants in it will grow beautifully. But under field conditions the principal method of nourishing plants does not consist in mineralizing the organic substances introduced into the soil.

This way of obtaining organic matter, a crop, from organic fertilization is about the same as using rags as raw material for the cotton industry. Of course rags should be utilized, but they are not the main raw material for that industry.

Materialist science showed long ago that a mighty process of rotation was, is and will be going on in nature—the conversion of compounds of the chemical elements of inorganic bodies into organic bodies, and vice versa.

Somewhere, sometime, somehow the living for the first time evolved out of the non-living, and today any particle of a living body may be obtained from non-living nature (food) by the agency of a living body. To master part of this natural process—the transformation of unassimilable compounds of chemical elements of the soil and air into forms assimilable by plants—means to master the soil nutrition of plants. That, indeed, is the way to work out more and more rational methods of fertilizer application and field cultivation.

As already stated, organic manuring is required for podzol soils of low fertility in order to ensure the normal vital activity of certain species of micro-organisms without which the entire remaining chain of other species of soil micro-organisms ceases its vital activity, causing the plant to starve.

Unfortunately certain agrochemists believe that the introduction of organic substance into the soil to "victual" microbes through whose agency the plants are nourished means a squandering of collective- and state-farm funds. But it is clear from what has been said above that this is precisely the main way to convert the unassimilable forms into assimilable forms, the inorganic mineral substances in the soil and air into plant food. If we intend to get big wheat

yields on podzol soil of low fertility, we must "victual" the micro-organisms through whose agency the wheat plants derive their nourishment from the soil. And it turns out that to get good yield figures, 4 tons of the organic-phosphoric-limestone mixture instead of 20-40 tons of manure is enough.

* * *

We must now go into the question of the depth at which fertilizers should be worked into the soil. Those agronomists and agrochemists who think that fertilizers, including water-insoluble ones, should be ploughed in deeply are absolutely mistaken.

On the experimental farm Gorki Leninskiye of the Academy of Agricultural Sciences they have not been ploughing down mineral fertilizers—superphosphates, ground phosphorite and lime—during the last few years. These fertilizers are introduced at the seed level or, what amounts to the same thing, at the depth of the pre-sowing cultivation. In the experiments now conducted here the efficacy of even mineral fertilizers alone, without the admixture of organic fertilizers, is considerably greater than it used to be when fertilizers were ploughed down.

The deep ploughing of mineral fertilizer is usually justified by reference to the fact that the upper stratum of the soil dries out sooner than the lower one. The earth, i.e., the soil, of course, begins to dry at the top. It should, however, also be borne in mind that the soil gets moisture from the top. But organisms, whether animal or vegetable, do not take in food uninterruptedly. The plant organism absorbs food neither uninterruptedly, nor every minute, nor every second. What we have in mind here is not the actual assimilation or dissimilation, not the nutrition of the body of an organism, but the taking-in of food from without.

It is of the utmost importance that fertilizers should be introduced into the upper stratum of the soil because it is here that in the main the food for the plants is prepared,

that it is converted from unassimilable into assimilable forms. It is through the upper layer that air penetrates into the soil and hence it is in this layer that conditions are created favouring the vital activity of aerobic micro-organisms. The upper stratum of the soil, down to about 10 cm., constitutes, figuratively speaking, the "kitchen," where the food for plants is prepared, and not only for grass plants but also for ligneous species, whose roots reach down to a depth of many metres.

Therefore the application of superphosphates and even ground phosphorite mixed with limestone materials and organic fertilizers to the upper layer constitutes one of the essential factors of greater fertilizer efficiency.

The depth at which phosphoric fertilizers are to be worked in is of considerable importance. It should be discussed all-sidedly and given practical tests.

We have no right to overlook the fact that abroad superphosphate was and is nowhere practically ploughed down to 20 cm. or more. In pre-revolutionary Russia superphosphate was also not ploughed down deeply under sugar beet on landlord land. It was not fortuitous that after the collective and state farms began to deep-plough superphosphates on the recommendation of the agrochemists, advanced agriculturists amplified the recommendation by adding the method of introducing superphosphates at small depths as supplementary nutrition.

* * *

Let us return to the problems relating to the specific features of the microflora.

Without the new ideas about the formation of species that have been evolved by science in our country during the last few years, we would not have been able to conceive, even in a general way, the biological process of the soil nutrition of plants.

For the question arises: If every species of plant or group

of related plant species has its specific soil micro-organisms, then how is it that any one of the many dozens and hundreds of plant species sown in any one section can thrive there? Where do the micro-organisms specific for each one of them come from in the soil?

Apparently there is this alternative: either the idea that every plant species has its specific species of soil micro-organism is a fiction, or plants do not feed through the agency of soil microflora. Recent conceptions of species conversion supply the answer to these questions.

By now a multitude of facts have been arrayed which tend to show that it is possible to transform some species into others. And the strong point about these facts is that anyone who wants to can find them anew any year. One need only know where to look for them or what conditions must prevail for such transformations to take place.

In microbiology too quite a number of cases of the conversion of one species into another have been recorded.

If only the roots of the plants we have sown appear in the soil and if there are no microbes there specific for these plants but there are others, then, due to the action of substances secreted by the roots, microbes that were not specific for the roots of the particular plant species are turned into specific ones. In some cases this process goes on faster than in others.

We shall now set forth certain ideas on the transformation of micro-organisms in the soil. So far these are only suppositions that must be fortified by factual material.

Everything tends to show that wherever wheat is sown, specific micro-organisms connected with its roots will inevitably appear after a short interval of time. In a number of cases they most likely come into existence from other species. With some plant species this process of changing micro-organisms may take less time, with other species, for instance legumes, it may take more. To grow a good crop of clover, lucerne, lupine, etc., it is trerefore necessary to infect the seeds artificially with suitable species

of nodule bacteria, as otherwise such bacteria will take long to appear in the ground and it will be impossible to get a good crop on that section the first year.

In the experiments mentioned above, blue lupine was the only cultivated plant that failed to respond to the organic-phosphoric-limestone fertilizer mixture. The point is that in the fields of the experimental farm of the Academy of Agricultural Sciences blue lupine was never grown before and consequently there were no nodule bacteria suitable for its roots available. The lupine seeds had not been treated with nitrogen before sowing. The conversion of non-specific bacteria into specific bacteria is a relatively slow process in the case of blue lupine. Hence in this case the microbiological chain by whose agency lupine is fed lacked one link and therefore the fertilizer was useless to it. Lupine was equally bad on both the fertilized and unfertilized plots. But at the end of August big nodule bacteria began to appear on the roots of most of the lupine plants. It is hard to assume that nodule bacteria were brought in from somewhere outside. There can be no doubt that they formed anew.

* * *

I must now dwell for a short while at least on the work of T. S. Maltsev. What Maltsev is doing now about improving soil fertility by proper treatment and by sowing annual agricultural crops is wholly and entirely in harmony with V. R. Williams's teaching concerning soil fertility, and is a development of this teaching.

Some scientists entertain the wrong notion that by feeding on the soil plants exhaust it. But to those who know Williams's theory it is perfectly clear that the plants and soil micro-organisms create the soil and its fertility. Without plants and micro-organisms connected with them there would be no soil altogether but only bare stones, marl. That is the reason why Maltsev is working on a method of improving soil fertility by cultivating annual plants, making use of the

laws already discovered by science, and discovers new laws governing soil fertility. Tillage methods are of particular importance in this matter and so is crop rotation.

It follows from all that has been said above that in settling the question of crop rotation the laws governing the life of soil micro-organisms must be taken into account. The soil micro-organisms suitable for the roots of particular plants, while accumulating metabolic products in the course of their vital activity, cannot live constantly under these conditions if there is no outflow of these metabolic products. The active vital functioning of the micro-organisms requires a change of crops and therefore a change of the microbes. What is bad for some species of micro-organisms is an essential condition of life to others.

The root nourishment of plants proceeds through the agency of soil micro-organisms suitable for the plant species concerned. Hence any set of agrotechnical measures, any agrotechnical measure—harrowing, cultivation, inversion of the soil with plough and skim-coulter, i.e., ploughing-up, non-inversion of the soil, i.e., no ploughing-up—should be performed not only for the purpose of accumulating moisture and keeping it in the soil and not only to control weeds and prevent their choking up fields, but also to create better conditions of life for the various links in the chain of soil micro-organisms.

It may not be amiss to adduce the example of the experimental winter-wheat sowing in the autumn of 1954 at Gorki Leninskiye. An appraisal by sight showed that the wheat planted after maize on a section which had not been ploughed up but only disked was in good condition. Plants growing after winter wheat in sections where the soil was turned up in ploughing by a plough with skim-coulter also looked well. But in sections where wheat was sown after wheat and the soil was tilled without inversion of the soil, the plants were slightly yellowish. Looked at from the biological angle of the soil nutrition of plants we can understand this phenomenon.

If crops rotate the upper layer of the soil may be turned less often than every year. In such cases the soil is not ploughed the usual way but instead is loosened fine and deep without moldboard, as Maltsev suggests. The plants will not suffer from this because with the change in the plant roots the soil microflora also changes. If, however, the single-crop system is practised for a number of years, such as cereals after cereals, then to my mind the upper layer of the soil must be turned more frequently, though not annually, in order to create favourable conditions for the microbes, to remove the noxious products of metabolism.

This serves to explain why in science, in the history of agriculture, the question has been so often raised: to plough or not to plough, to loosen or not to loosen the soil, to turn over or not to turn over the soil. Practice, in spite of it all, has arrived at the plough with skim-coulter. And it is a good thing it did. But this does not mean that the soil must annually be turned up in ploughing. The soil should be given a rest once in a while from the plough.

* * *

It is often said that Lysenko underrates agrochemistry and excludes it from agronomy. That simply is not true. I always both orally and in writing (which can easily be checked in my articles) have recognized the merits of chemistry. I know that chemistry in its development evolved biology. To my great regret, biology as a science has fallen behind the times.

I am, moreover, perfectly aware of the fact that without the advancement of the chemical and physical sciences there can be no biological science.

Now dissatisfaction is expressed over another thing, namely, that Lysenko does not recognize agrochemists as agronomists, considering them chemists. What a ridiculous reproach! Where did you ever hear machine-and-tractor station engineers voice complaint at being called engineers or

engineering specialists and not agronomists? What sort of chemist is he who feels offended if he is called a chemist and not an agronomist? The one may be referred to as a chemist, another as an agrochemist. Does that make any substantial difference?

What is included in the concept "agrobiology" or "agrochemistry"? Now I am considered an agrobiologist, a scientific worker who seeks to discover biological laws; however, not any biological law at all existing in nature, but only such laws as enable the agronomist to create, propose, test various agrotechnical ways and means of solving particular important practical problems in order to lighten work and increase the yields of agricultural crops. But the laws the agrobiologist discovers deal with biology and not agronomics. That is the only way biology develops as a science: not simply by proceeding from case to case, but by settling day by day the practical agronomic, agricultural problems. In this way agrobiology comes to mean biology which examines nature from the angle of agronomy. Similarly, medical biology, for instance, studies biological phenomena from the point of view of medicine, the curing of people; veterinary biology—from the point of view of veterinary science, the medical treatment of animals.

Agrochemistry reveals the chemical laws that it is necessary to know in order to settle practical agronomic problems. Agrochemistry is not agronomics, but chemistry investigating the chemical processes going on in the soil, in plants, in fertilizer materials, etc., with the purpose of achieving agronomic, agricultural tasks.

This definition of agrochemistry is not new. It was given to all of us by a learned authority on agrochemistry, the scientist Dmitry Nikolayevich Pryanishnikov. I have repeatedly given it as my opinion that it is necessary to study agronomic chemistry every day, constantly to elaborate the laws of soil chemistry, the chemistry of the nutrition of plants, inclusive of fertilizers, to discover the chemistry of

the plants themselves, i.e., it is imperative to study the chemistry that agriculture stands in need of.

But the soil nutrition of plants, the fertilization of the fields, is a biological process. No matter how many chemical laws chemists may have discovered, no matter how thoroughly they may have studied the chemical changes going on in the egg of a hen during its incubation, you cannot hatch a chick from an egg on the basis of laws laid down by chemists. And people learned long ago how to hatch chickens by satisfying the biological requirements of the hen embryo.

D. N. Pryanishnikov holds that "only if we know the requirements of the plant concerned and the properties of its environment can we select methods of acting on the environment (mostly the soil) and on the plant itself that will enable us to alter to some extent the properties of the surrounding environment in accordance with what the plant requires to increase its yield. To study these methods is the business of agriculture."*

The advancement of science brings to the fore ever new problems that need all-sided discussion. Hence controversies. Scientific truth cannot be obtained without controversy. The only thing important here is that controversies should not be conducted for their own sake but for the sake of ascertaining the truth. And we take that to be true which helps the collective and state farms to increase the yield of their crops.

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* D. N. Pryanishnikov, *Agrochemistry*, Selkhozgiz, 1940, p. 12., Russ. Ed.

LET US CARRY INTO EFFECT THE DECISIONS OF THE JANUARY PLENARY SESSION OF THE C.C., C.P.S.U.

I*

In the regions of the south-east, square-pocket sown maize will solve not only the fodder problem—the obtaining of a sufficient supply of fodder grain and succulent feed—but at the same time also the problem of saving and accumulating moisture in the soil, that is to say, it will also act the part of fallow land. The importance of bare and of early clean fallow in the south-east districts is generally known. Fallow fields retain moisture well and rid the soil of weeds.

Can square-pocket sown maize help to accumulate moisture and weed the soil, i.e., function as fallow under the conditions of the South-East?

Let us clarify this problem, at least briefly. If maize is cultivated the square-pocket way, the sown soil will be tilled lengthwise and crosswise much more thoroughly than when cultivating bare fallow. It stands to reason that a field with a growing crop will get more attention and be of greater interest than a bare fallow field. I do not mean by this that the fallow area in the south-east districts should be reduced. What I do mean is that the sowing of maize has the

* Revised and abridged stenographic record of an address delivered at a conference of agricultural officials of the regions of the south-east held on March 18, 1955, in the city of Saratov.

effect of increasing the fallow land sector. The cultivation of square-pocket sown maize should be done in the two directions. When practising this method of tillage the soil of the maize fields will be covered all the time with a thin loose layer, as a result of which direct evaporation of soil moisture ceases, just as is the case with well-tilled bare fallow; and that good and timely mechanized cultivation of maize fields will simultaneously destroy weed sprouts.

The objection may be raised that maize plants dry up the soil, especially in droughty years. Indeed, there are cases when maize does drain the soil very much of moisture and yet it yields a good crop of grain and vegetation. On the other hand, oats and spring wheat produce almost no crop at all in the south-east districts in very dry years.

The further objection will be raised that some years in the south-east may be so dry that even maize crops will utterly fail. Yes, they may fail but only if they are sown too densely and if, besides, the tillage and thinning of the plantings is done badly and too late.

I shall cite here a few of the results of some old experiments of south-east research institutes. At the Bezenchuk experimental station the average maize yield between 1904 and 1935 was 16.4 centners of grain per ha. and the average oat yield 13.7 centners. As you see, the maize yield was greater. But it must be remembered that in that instance they sowed maize varieties of low yield and growth, that they sowed only maize varieties which in any year yield ripe, dry seed.

Now let us examine the maize-yield figures at the same station in the droughtiest years. In 1911 1.9 centners of oats were obtained per ha. and maize 14.3 centners per ha. In 1921, the year we all remember for its dryness, the oat yield was 1.1 centners and the maize yield 8.1 centners per ha. In 1924 the respective figures were 4.1 centners and 16.2 centners.

In the dry year of 1954 the south-east produced a bad maize crop on many collective and state farms. It was pre-

cisely last year, although it was also a droughty one, that maize in the south-east districts could have produced a very good crop if it had been tilled well. In dry districts the number of plants grown per unit of area should be small A large number will suck the soil dry and yield no crop. There will be enough moisture for a smaller number of plants even if its supply in the soil is the same. The plants will manage to survive the dry period and yield a good crop. In general it should be remembered that the less moisture there is in the soil and the more parched the area is, the relatively fewer plants should be reared per unit of area. In square-pocket sowing only one plant should go to each pocket and the pockets should not be laid out more closely than 70×70 cm., or, still better, 80×80 cm.

As soon as spring sets in, the soil must of course be harrowed to preserve the moisture. But after the maize is sown the field must be tilled criss-cross as often as possible to keep the soil weed-free and the top soil friable.

In the maize fields of the arid districts of the south-east the winter-sown sector may well be enlarged, it seems to me. In these districts winter grains (expecially winter wheat) quite frequently winter badly. The main reason for their bad wintering in these parts and in Siberia is the friable soil. This is now well-established. Winter rye and winter wheat sown in Siberia in uncultivated stubble overwinter well even in those years when winter crops sown in fallow fields winter badly. There is therefore every reason to believe that winter cereals—rye and wheat—sown after the maize is harvested will winter well if the maize was well cultivated during the vegetative season. The one thing required is that these fields should not be reploughed after the maize has been reaped, but should be shallow-tilled with cultivators or disk-harrows. In such fields the soil will be more compact and this facilitates the wintering of the winter crops in many respects. Moreover, the first snow that falls will be retained by the stubble and will cover up the sprouts of the winter crops. And if every 15th or 20th row

of maize stalks is left in the field, the maize stubble and the tall stalks remaining will pile up a lot of snow during the winter. Such a quantity of snow will, it seems to me, provide not less moisture for the soil than the summer precipitation supplied to the fallow fields during the preceding summer.

Some comrades propose that in the arid trans-Volga areas, especially in Stalingrad Region, most of the fallow fields should be sown to spring wheat so that they could accumulate the precipitated moisture while they lie fallow. In my opinion, if maize is to be grown in these regions in these same fields, it must not be sown densely but at distances of 80×80 cm., and after the cobs are garnered 15-20 per cent of the stalks should be left standing. During the winter they will retain enough snow in the Volga districts for the soil to be moistened better than fallow fields. Such fields should not be ploughed in spring but disked and sown with spring wheat as early as possible.

Thus maize may form a good preceding crop in the districts of the south-east for both winter cereals and spring wheat. Neither in the first nor in the second instance should fields be ploughed after maize but only disked; moreover, if sown to spring wheat the disking should be done in spring and not in the autumn so as not to break the stalks.

In general, in the districts of the south-east, maize will be not only a highly important fodder crop, supplying feeder grain and succulent fodder, but it will also be a means of fighting for efficiency in agriculture and for the accumulation of soil moisture in arid regions, a means of combating weeds and of raising crop yields of winter and spring cereals.

On preparing maize seeds for sowing. At the present time collective and state farms of the south-east districts are receiving maize seeds for sowing. Unfortunately, these seeds in many cases contain too much moisture and should therefore be dried at once.

This is done by spreading the seeds in a thin layer in

warm premises and stirring them frequently. It is very important that the seeds should be dried and warmed promptly; otherwise they lose their germinating capacity or their growing energy will be deficient.

I believe that this year, as well as in the next, southern varieties of maize seeds will mostly be sown in south-east collective and state farms and also in the central and northern belt of the Soviet Union. In these districts the said varieties ripen late. In the south-east they have long been cultivating varieties ripening much earlier, for instance the Bezenchuk varieties. These varieties, particularly those from Siberia, for example, Beloyaroye Psheno, the Slavgorod variety and others, are good because of their early ripening. But they are of low growth, have small cobs, and produce a considerably smaller crop of seeds in the milk-wax stage than the late-maturing southern varieties brought from other parts of the country.

The decision of the January 1955 Plenary Session of the Central Committee of our Party points out that in the next few years a change in favour of using hybrid maize seeds must be effected. Now what hybrid seeds will be most suitable for the south-east districts? I think that at least in the initial period the most suitable for these districts will be the hybrid seeds obtained by crossing southern medium-ripening and late-ripening varieties with early-ripening Volga varieties, and also with the ultra-early-ripening Siberian varieties. The seeds of such crosses will produce early-ripening and at the same time vigorous tall plants with big cobs and big seed crops in the milk-wax stage.

It is therefore exceedingly important that the research institutions, as well as the district seed farms and state farms, should propagate this very year the early-maturing varieties of maize and at the same time carry out the greatest possible number of crosses of early-maturing varieties with the late-maturing varieties brought in from elsewhere. After testing the hybrid seeds of the indicated combinations for their yield capacity it will be possible to select for each

district the best pairs of varieties for the production of hybrid seeds.

Briefly on the cultivation of millet in the south-east districts. In many respects millet-growing is as valuable to these districts as maize-growing. Like maize, millet can yield very big crops per unit of area. Why can they produce considerably bigger crops than wheat or oats? The explanation is the peculiar structure of their organs of fructification.

In millet, for instance, one panicle may yield, under bad conditions, a seed crop of no more than 0.5 gm., but under very good conditions 100 and even 200 gm. In wheat and rye the size of the ear similarly depends on the conditions of rearing, but their ears cannot change to such a great extent. No matter how good the conditions created for wheat may be, you cannot get more than 1.5-2 gm. of seed from an ear of wheat of any of the varieties existing in our country, while millet, as I have already said, may yield 100 and even 200 gm. of seed per panicle. A single maize cob can yield up to 300 gm. of grains and even more.

It is a matter of general knowledge that in arid places no agricultural plant should be sown very densely, for a crop thus sown will use up the moisture too quickly, the plants will be parched and will yield no crop. Nor may wheat, oats or barley be sown too sparsely, since each ear of these cereals produces but few seeds and when there are few ears the crop per unit of area is small. As for maize and millet, the number of plants can be regulated, which is particularly important in arid regions. The number of maize or millet plants per unit of area must here be determined by the need to obtain sufficient moisture for all. And a good crop can be had from each hectare even with a small number of plants, as each separate maize and millet plant can produce a great number of grains. But for that it is, of course, necessary that the maize should be sown in squares and that millet should be sown on old ploughland in wide rows. Otherwise dense millet fields can easily be choked up with weeds, and thinly sown fields all the more so.

The collective and state farms in the south-east districts have had much and instructive experience of millet cultivation. It is gratifying to learn that they are again seriously taking up its cultivation. Chkalov Region alone has undertaken to extend the millet area this year to as much as a million hectares.

Before the war I saw very fine millet fields in a number of south-east regions. I recollect in particular the crops in the Sol-Iletsk district of Chkalov Region. There was a drought that year and a sweltering heat. All verdure round about was drying up; the wheat fields had a puny look. Against this background, magnificent unbroken wide-row planted millet fields of 200-400 ha. each stood out in bold relief. If you penetrated 300-400 metres into this massive vegetation you felt yourself transported into an entirely different locality: no dust, a moist air, large-panicled millet up to your waist—a sight no agronomist can ever forget.

Where did the millet plants get moisture in such a droughty year? The answer clearly follows from what has already been said: the millet had been sown in wide rows, i.e., each unit of area had only a small number of plants, the soil between the rows had been loosened well and in due time so that almost no water evaporated and enough moisture remained for the relatively few plants. Thus the millet yield of such vast fields amounted to 20-30 and even more centners of grain per ha.

On the fertilization of fields under millet or maize in the districts of the south-east. On collective and state farms having superphosphate or ground phosphorite I advise using at least 1 centner of powdered superphosphate or 2 centners of ground phosphorite and mixing these mineral phosphoric fertilizers with 3-5 tons of good humus.

But the humus must be carefully scrutinized to see that it does not contain weed seeds. If the maize is hand-sown this organic-phosphoric mixture must be applied by the handful, introducing 200-300 gm. into each pocket. When sowing millet, however, the organic-phosphoric mixture

must be broadcast before the pre-sowing cultivation and worked in by the cultivator.

But if there is no phosphoric fertilizer on the farm, it is desirable that at least 4-6 tons per ha. of humus alone should be introduced into the maize pockets or broadcast over the millet fields.

It goes without saying that in the districts of the south-east it is essential at the very inception of spring to prevent the escape of moisture on all sections, including of course those that will be sown to maize or millet, to cultivate the land in good time and harrow it once more, and thus to collect and conserve the moisture in the soil and make it weed-free.

Millet seeds must be disinfected against smut and vernalized. In the south-east districts vernalization has proved its worth long ago and it is my advice that the vernalization of seeds should be practised more extensively not only in the case of millet but also of spring wheat. If asked what increase the grain yield shows in the case of spring wheat if the seeds are vernalized, I am able to reply that in the south-east districts it is the same as if the same wheat had been sown earlier (3-5 days) but in well-cultivated soil. And we all know the significance in these parts of sowing 3-5 days earlier, provided the soil is well tilled before the sowing.

How millet should be sown in the districts of the south-east: in wide rows or in a dense mass? In fields of old cultivation in normal early seasons millet should be sown in wide rows. If the sowing is dense and particularly if early, the millet is choked by weeds.

Old fields can be sown to millet also densely, as comrades from Ulyanov Region suggest. But this requires that from early spring to the time of sowing the soil should be made weed-free by good cultivation. For this purpose millet sowing has to be delayed to the middle and sometimes even the end of May. But this harbours the danger that in con-

sequence of using soil cultivators which dry the soil (something impermissible) instead of cultivators provided with knives or duck-foot harrows, or when the cultivation is delayed and weeds already begin to grow, the top soil may get too dry, so that it will be difficult to obtain millet sprouts. Hence on old soil millet may also be sown densely, but, as aforesaid, it is necessary 2 or 3 times before the sowing to cultivate the soil with mouldboardless implements that will not dry up the soil, to clear it of weeds, and to husband the moisture in the upper layer of the soil. Only on that condition can one guarantee a good millet crop in the south-east districts even when sowing old sections densely.

On clean virgin soil millet must be sown not in wide rows but densely and, still better, in narrow rows, or it must be criss-crossed. On weed-free virgin soil a fine millet crop can be obtained when sown densely and as this is a densely sown field no row tilling is needed. On virgin land millet must be sown immediately after the early cereals.

On harvesting millet. The harvesting of big dense millet crops has up to the present been a difficult job. Weil matured millet that produces a crop in the neighbourhood of 20-30 centners per ha. and more readily sheds when the reaping is delayed, i.e., loses much grain. Hence the very practical proposal to harvest millet in two stages, i.e., first to windrow the crop and then to thrash it with pick-up combines.

II*

The report of Comrade N. S. Khrushchov at the January Plenary Session of the C.C., C.P.S.U. and the decisions of that session point out the link that must be grasped to set the whole chain in motion (and it will be set in motion)

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* Revised and abridged stenographic copy of an address delivered at a conference of agricultural officials of the central chernozem zone on March 30, 1955, in the city of Voronezh.

and speedily to raise the collective and state farms, all agriculture, to the proper level. That link is the extensive cultivation of maize. Maize is of tremendous importance to almost every district in the Soviet Union and particularly so to the central chernozem belt, because there both soil and climatic conditions are most suitable for it. Maize can be made to grow on any soil or in any climate but nowhere else are the conditions of its cultivation so favourable as in the chernozem zone.

If properly raised, maize will yield very handsome crops. It is a huge reserve, which when used will make it possible to double and even treble the grain fund necessary to whip animal husbandry into proper shape.

Together with the central chernozem regions' most important industrial crop—sugar-beet—maize holds the key to a successful solution of the paramount problem of improving agricultural methods. Here it must be stressed primarily that if maize is correctly reared, i.e., if the fields are cultivated in good time both lengthwise and crosswise and the crop is harvested in the milk-wax stage, it will be the best predecessor for winter wheat in these districts.

Winter wheat sown in an unploughed maize field will winter more safely and its yield will be no less than if it were sown in bare fallow.

Wheat will grow particularly well if some of the maize stalks are left standing in the field for snow retention. This use of maize stalks to keep back snow in winter-wheat fields makes the sowing of winter wheat on top of maize a good link in the chain of crop rotation.

It is general knowledge that fertilization of fields holds an important place in the system of crop rotation. In recent years the Academy of Agricultural Sciences has been investigating the laws governing the soil nutrition of plants and has evolved a theory concerning this question. At the present time more rational methods of field manuring in both the chernozem and podzol zones are being devised on a new theoretical basis.

Fields must of course be fertilized differently not only in different zones but also in different sections and for different agricultural crops. In view of all this it may already now be safely asserted that the application of a mixture of organic and phosphoric fertilizer in doses a fraction of the usual size produces the same increase in yield as results from the so-called normal doses of manure and phosphoric fertilizer.

Workers of the central chernozem zone are well advised to employ organic fertilizer—rotten or half-rotten manure and humus—mixed with superphosphate and even with ground phosphorite also for sugar-beet crops. Such a fertilizer mixture produces a greater yield increase than the separate introduction of the same fertilizers for sugar-beet. The same holds good for other crops too.

Just now the winter crops must be given their supplemental feeding. If the per-ha. superphosphate dose is mixed with at least a ton or even half a ton of organic fertilizer, the resultant mixture will just about double the efficacy of the superphosphate. Ground phosphorite has little effect on carbonate soils; but if ground phosphorite is mixed with organic fertilizers, with one or two tons of organic matter, one may find out for oneself that ground phosphorite can be highly efficacious even on carbonate soils.

Let us pass on to the maize fertilization problem. A collective-farm chairman from Orel Region spoke before me. He said that if the land is properly manured for a hemp crop, there will be hemp, but no maize because there will not be enough manure for the latter. And if the manure is applied to the maize fields, there will be no hemp. One is therefore confronted with the following alternative: either a good hemp crop or a good maize crop. This, of course, is not the right way to put the question. Both hemp and maize are needed; and good crops of both plants not only can but must be obtained. One need only use the organic-phosphoric fertilizer mixture; it manures all crops. For maize fields it is enough to put 200-300 gm. of organic-phosphoric

mixture in each pocket and to till the land properly and in due time to obtain excellent crops. And there is enough fertilizer to put that amount of the mixture into each hole. Organic-phosphoric fertilizer mixtures are also good as supplemental feeding for maize fields. The mixture must be introduced before they are cultivated.

Another important central chernozem zone crop is potatoes. Potato-growing is of ancient date in these parts. Nevertheless potato crops are small here. The reasons are well known: bad cultivation of the soil and bad care taken of the plantings, bad planting material and failure to use fertilizer. The value of applying organic-phosphoric fertilizer mixtures when planting potatoes in pockets is widely known. In mechanical potato planting organic-phosphoric mixtures can be introduced not only into the pockets but also in broadcast sowing. In that case immediately before planting, an organic-phosphoric mixture of 4-6 tons per ha. is broadcast over the field. The fertilizers are left uncovered and when the potato planters cross the field the entire upper layer of the soil together with the fertilizers lying on top of it will be transferred by the disks to the tubers, i.e., collected in the roller by which the potato tubers are covered on planting. Such fertilizing is very effective and therefore whenever it is impossible to introduce the organic-phosphoric mixture into the pockets it can be broadcast before the mechanical planting of the potatoes.

The Communist Party and the Soviet Government are taking the necessary steps to increase superphosphate production; still many farms justly complain of its shortage.

The new method of fertilizing fields—the employment of organic-phosphoric mixtures—makes it possible to use our ground phosphorite resources much more rationally. In the central chernozem zone ground phosphorite must be used much more extensively than before, but it must absolutely be mixed with humus or rotten manure. Such a mixture will

make an excellent fertilizer also for sugar-beet, maize and potatoes.

For such mixtures it is necessary to take an organic fertilizer—from 0.5 to 2 tons of rotten manure and 2-3 centners of ground phosphorite per ha.

Now I shall dwell on the problem of improving potato planting material. Here mention ought to be made of the method of summer-planting potatoes, particularly of the early-ripening varieties.

Tubers grown by the summer-planting method and used the following year as planting material produce considerably bigger crops than seed tubers of the same variety grown from tubers planted, as usual, in spring.

If the planting material is to be improved, at least part of the seed plots planted to early potato varieties must be planted as early as 1955 in the central chernozem zone and in the southern districts of the country by the summer-planting method. It is self-understood that to get good potato crops by the summer-planting method, the sections concerned must be properly tilled from early spring on.

In conclusion a few words on leguminous crops which, though occupying in the central chernozem zone a comparatively small percentage of the sowing area, could and should play an important part among man's foods.

We are concerned here with beans, peas and lentils. All these plants make good protein-rich foods. It is extremely important to call attention to the need of enlarging these crop yields and extending their sowing areas.

I shall now reply to some of the questions put to me.

1. Isn't it too early now to feed the winter grains with a supplemental dose of organic-phosphoric fertilizer mixture? Can the fertilizer be placed on the cutting; won't water wash it off?

No, it won't; fertilize the winter crops with all possible speed!

2. What hybrid maize seeds are required for the central chernozem zone?

Here we need hybrids that will produce large cobs in the milk-wax stage at least 10-15 days before the first frosts set in that kill off maize plants, the idea being to have time to silo both the maize cobs and stalks on the farms.

The early-ripening maize varieties, particularly those from the south-east districts, and also the ultra-early-ripening Siberian varieties produce small cobs and plants of low growth, hence little greenery and grain.

Consequently, such varieties cannot produce good grain crops in the milk-wax stage. All the same I advised people time and again, and advise you too, to propagate these early and ultra-early varieties. They are very valuable in the central districts for crossing with the late-ripening southern varieties, from which big cobs are obtained. If we cross in the central zone districts the ultra-early-ripening Siberian varieties with the southern late-ripening ones, such crossings produce early-ripening and powerfully developed plants with big cobs already in the first generation.

It is necessary that as early as 1955 the research institute workers and also the advanced collective farmers and state-farm specialists should develop the propagation of early-ripening varieties and at the same time should cross these varieties with the late-ripening ones of the south. By comparative crop tests in the various districts the best combinations will be ascertained—the best pairs for crossing, with the purpose of obtaining hybrid seeds.

3. How does maize behave on slightly acidic and acidic soils?

If organic-phosphoric-limestone mixture is introduced into the pockets, maize may thrive not only on acidulous but also on acidic soil.

It is to be recommended here that in the districts of the central chernozem zone the by-products of beet-sugar

manufacturing should be used as much as possible. Mixed with organic fertilizer and broadcast before sowing any crop, including maize, it should be incorporated when cultivating the land before the sowing.

III*

Field fertilization plays an important part in the rapid development of agriculture in the non-chernozem zone where much of the soil is acidic podzol. The field fertilization problem is the problem of the soil nutrition of plants, a process that takes place on the basis of the laws of biology. This means that workers dealing with the science of plant nutrition, of field fertilization, must study biology, the processes of nurturing plants.

For the last few years agronomic science discovered a number of laws governing that process. This has enabled us to propose (and we have been proposing for several years now for verification on the collective and state farms) more rational methods of fertilization.

These more rational ways and means of fertilizing fields come down to the so-called small doses, as many are aware of. The crux of the matter is of course not the small doses. The soil-nutrition process of plants goes on through the agency of soil micro-organisms specific for the particular species or group of related species of plants. It may well be said that the soil micro-organisms play the same part in the nourishment of plants as the digestive tract in the nourishment of animals.

To show that the soil micro-organisms are of great importance in the nourishment of plants, let us turn to some well-known facts. No one will deny that putting even 100

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* Revised and abridged stenographic text of an address delivered at a conference of agricultural officials of the regions and autonomous republics of the central non-chernozem zone on April 6, 1955, in the city of Moscow.

tons per ha. of recently dug peat into podzol soil will raise fertility very little. But if this peat is infected with beneficial microflora, i.e., is composted with manure, the picture is entirely changed: 15-20 tons of such peat manure compost is equal in value to 15-20 tons of high-grade manure. This one example alone indicates that suitable useful micro-organisms play a tremendous part in the nourishment of plants. We must therefore create the necessary conditions of life for useful soil micro-organisms, though we do not yet know the names of the species they belong to (microbiology can and will ascertain them). If we ponder over the essence of each method of tilling the soil and likewise over each manner of fertilizing the fields, it becomes clear that there is one ultimate goal they all seek to attain: to create the conditions of life of those soil micro-organisms that bring about the root nutrition of plants.

Even the so-called low-productive sandy and podzol acidic soils contain, it appears, almost everything to produce a good crop of even such exacting plants as cucumbers, cabbage, maize and wheat. However these cultivated plants produce no crop on such soils. This is explained by the circumstance that the soil in question lacks certain conditions or substances requisite to sustain the life not of the plant itself, but of the micro-organisms whose enzymes transform in the soil the chemical elements and their compounds which the plants cannct assimilate into nutrients which they can assimilate.

If we were to call forth in such poor soil the microbiological process necessary for the nutrition of the plants in question by creating the requisite conditions or by introducing the deficient substances, then good crops even of cucumbers could be obtained on these soils. If this is true of the exacting cucumber, then so much the more so of wheat, maize and the like.

I shall make no reference to the experiments performed in the experimental field of the Lenin Academy of Agricultural Sciences of the U.S.S.R. at Gorki Leninskiye. I

have spoken and written about them on numerous occasions. But I shall cite the results of individual 1954 experiments obtained in the collective farms of Arzamas Region. In the Kalinin Collective Farm the winter rye crop amounted to 14 centners without fertilizer. When a per-ha. mixture composed of 2 tons of manure and 3 centners of ground dolomite was employed, it obtained 25.3 centners of rye grain per ha. In the Lenin Collective Farm of the Glukhov Machine-and-Tractor Station, the per-ha. rye yield was 4 centners without fertilizer. When a fertilizer mixture was introduced—2 tons of manure and 3 centners of ground dolomite—that figure rose to 9 centners. In the Zhdanov Collective Farm, the rye yield without fertilizer was 6 centners, and 13 centners with the application per ha. of 2 tons of manure mixed with 3 centners of ground dolomite. In the same collective farm the introduction of 20 tons of manure per ha. yielded a crop of 13.7 centners. In the Kalinin Collective Farm of the Glukhov Machine-and-Tractor Station the crop yield was 8 centners without fertilizer and 22.5 centners when dressed with 2 tons of manure per ha. mixed with 3 centners of ground dolomite.

I purposely quoted only those examples where no superphosphate or ground phosphorite was added to the fertilizer mixture but only limestone material (in the particular case, ground dolomite) mixed with 2 tons of manure or humus. There is much talk about there not being enough mineral phosphoric fertilizer, superphosphate, to go round. That's true. But the Party and the Government are not leaving a stone unturned to increase the output of mineral fertilizers. Their manufacture is increasing and is sure to double and even treble within a very few years. But the time is still far off when the entire area of the Soviet Union in need of mineral fertilizer will get as much of it as it wants. Therefore, if yields in the non-chernozem zone are to be improved it is imperative that, in addition to the use of mineral fertilizer manufactured by our industry, limestone materials and local organic manure should be applied

on the widest possible scale. Limestone-material deposits occur in ample quantities in all regions of the non-chernozem zone in the shape of ground dolomite, limestone, marl, tufa, etc.

How are limestone materials best applied to acidic soils and in what doses?

I have nothing against using big doses of limestone materials, of the order of 3-5 tons per ha., although it is not always of advantage to invest much labour and material if the outlay is not soon recouped.

Everyone knows that the introduction of 5-6 tons of lime per ha. into acidic soil is useful in that it will increase yields, but only in case of clover. If 3-5 tons of lime per ha. are applied without manure to acidic non-peaty soil planted to other crops, no beneficial effect in the sense of increased yield will result.

The dosage of lime we recommend is not 30-50 centners per ha., but 3-5 centners, i.e., one-tenth as much. But it is essential that to these 3-5 centners of limestone material there should be added at least 2-3 tons, and still better 3-5 tons, of organic fertilizer and that they should be mixed with limestone fertilizers. If such a fertilizer mixture is applied to the soil superficially before the pre-sowing cultivation, the yield of any crop will increase more than if 30-50 centners of pure lime had been applied without any mixture with organic fertilizer.

All sectors containing acidic soils must annually be given 3-5 centners of lime per ha., mixed with small quantities of organic fertilizer. It is extremely useful to add to this mixture 2 centners of ground phosphorite and at least 0.5 centners of powdered superphosphate. If such a mixture of organic, phosphoric and limestone fertilizers is introduced before the pre-sowing cultivation or directly into the pockets when sowing acidic soils (as described in many experiments) it takes the place, in effectively raising yields, of 20-30 tons of manure and 30-50 centners of lime per ha. applied the usual way.

For the first period of time the so-called small doses of organic-mineral fertilizer mixtures we recommend must be applied in the form of a widely conceived experiment to all crops, first and foremost to maize. If such widely practised experiments prove useful, of which I have no doubt, the result will be that in 2 or 3 years the fields in the non-chernozem zone will receive no less than 9-10 million tons of limestone materials. I recollect that before 1954 our whole country applied yearly only a few hundreds of thousands of tons of lime at the rate of 3-6 tons per ha. In other words, under the new method of treating soil with lime mixed with organic fertilizer, and with lime-per-ha. doses cut to one tenth, the quantity of lime that will be employed in the non-chernozem zone will be 10-fold the amount used when dosages were big. In conjunction with this the total amount of manure and peat introduced must also be augmented by 100-200 per cent.

In the non-chernozem zone all fields planted to crops must be fertilized every year, but the methods employed and the fertilizers themselves must be such as do not require the expenditure of much energy and material per unit of area.

How, then, are the fields under maize to be fertilized in 1955 in the non-chernozem zone?

We must set apart for this purpose the best sections of the zone treated with organic fertilizers. Independently of this an organic-phosphoric-limestone mixture must be applied to all sections before sowing. If there is no phosphoric fertilizer on the farm, a mixture of organic and limestone fertilizer should be used. A supply of limestone materials for acidic soils must be on hand without fail. It is necessary to procure them for use as dressing. The same applies to manure and peat.

Limestone materials ought to be applied only when mixed with organic fertilizer. Lime alone, even if introduced into the pockets when the maize is sown, has no effect unless it is mixed with organic fertilizer. If the maize is hand-sown, 250-300 gm. of organic-phosphoric-limestone mixture must

be inserted into each pocket. The crop will then be good, provided the land is tilled properly.

How to proceed when maize will be machine-sown, an aim we must strive for? In that event 5-6 tons per ha. of the indicated mixture must be broadcast before the pre-sowing cultivation.

I shall now pass on to potatoes.

Raising potato yields is a paramount necessity. To raise that yield the fields have to be fertilized. This everybody knows. When potatoes are machine-planted—and this will mostly be the case in this zone, using the square-pocket method—4-6 tons and more per ha. of organic-mineral mixture should be broadcast before the machine-planting. Such fertilizer need not be covered up after the broadcasting. The disks of the potato planter rake up the topmost layer of the soil together with the fertilizers and in this manner form a ridge out of the fertilized soil. As a result the soil of the crest over the planted potato tubers will be well manured. It will be no worse than introducing the same quantity of this fertilizer per ha., 250-300 gm. into each tuber pocket. I call your special attention to the fact that when introducing fertilizer into potato pockets, limestone material is not to be used, as this may bring on the scab. On the contrary, as has already been explained, when fertilizer is applied to the pockets in maize-sowing it is exceedingly important to add limestone material to the organic fertilizer.

Extra nutrition of winter cereals and clover in the spring. When providing supplemental nutrition in spring for winter cereals and also for clover, every hectare should receive at least 0.5 tons, or, still better, 1-2 tons of organic fertilizer mixed with 1-2 centners of phosphoric and 3-5 centners of limestone fertilizer. If there is no phosphoric fertilizer, apply at least 3-5 centners of some limestone material mixed with organic fertilizer. There is no need to mix nitrogenous fertilizer with organic fertilizer to provide additional nutriment for winter crops.

A few words on bare and early fallow for the podzol zone. It is my opinion that loamy acidic podzol soil, particularly if sandy, ought not, during the warm part of the year, be left unsown to cultivated plants, be left in a fallow state.

In chernozem fields fallow is a useful thing, because chernozem humus, when the land lies fallow, is converted by microbes into nutrient substances for plants, whereas on podzol soils fallow fields are needed only to introduce into the soil strawy, undecomposed manure. And if no manure is introduced into podzol fallow, not only will no nutriment for plants accumulate but, on the contrary, the plant nutrients in the soil will diminish. Winter crops sown after an unfallowed preceding crop in a podzol section will fare better than such crops sown after fallow, if the land is not manured. Therefore if the methods of fertilization we propose are applied (and I am deeply convinced that they will become the general practice here) this will mean the end of bare and early fallows in the podzol zone. Neither from the point of view of biology nor of agronomy is there any need of clean fallow in this zone; and from the economic point of view, it means only loss.

IV*

The January Plenary Session of the C.C., C.P.S.U. pointed out that grain production in our country must be raised within the next few years to no less than ten thousand million poods** a year, inclusive of more than 4,000 million poods for forage. The task of increasing the produc-

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* Revised and abridged stenographic text of a speech delivered at a conference of agricultural officials of the regions and autonomous republics of the north-west on April 12, 1955, held in the city of Leningrad.

** 1 pood=16.38 kg.—*Ed.*

tion of forage grain must in the main be accomplished by the mass sowing of maize.

Maize has been grown for a long time, but always only to obtain the mature dry grain. That is the reason why in our country the cultivation of maize was widespread only in the south.

The Plenary Session spoke of an entirely different utilization of maize. In its decisions, in N. S. Khrushchov's report and also in its repeated explanations and instructions, new and great maize potentialities have been revealed. The question at issue is the utilization of maize grain in its milk-wax stage. The nutritive value of maize grain in the milk-wax stage is in no wise inferior to that of the fully ripe dry grain.

The siloing of maize cobs in the milk-wax stage makes it possible to preserve this valuable concentrated grain forage for a lengthy period of time. Besides, after the cobs are harvested in the milk-wax stage, there remains a green mass of stalks and leaves by siloing which fine succulent fodder may be obtained. This manner of utilizing maize has inaugurated the perspective of maize cultivation on the most extensive scale all over the Soviet Union.

The possibility of harvesting maize crops in the milk-wax stage with economic advantage is very important also for the southern districts, because there, owing to the earlier harvesting, a good crop of greenery can be obtained simultaneously; this after siloing makes excellent succulent livestock fodder for the winter.

The experimental maize sowing carried on in state and collective farms throughout the Soviet Union has shown that this cultivated plant may produce a crop which will by far exceed in fodder value the crop of any other cultivated plant. All this makes maize the principal forage both for the grain and the succulent fodder it simultaneously provides.

I recently received a booklet describing the 1954 maize-growing results in the Komi Autonomous S.S.R. Here, in

the fields of the Biological Station of the Komi A.S.S.R. and in the collective farms, 600-800 centners of maize were produced per ha. I must specify that the experiments referred to here were not performed on plots so many metres long and wide, but on fields measuring hectares and sown for production.

The Komi A.S.S.R. is almost the northernmost district of the U.S.S.R. It appears that in this district, where the vegetative season is only 2 or 3 months long, the experimental maize yield was 800 centners of greenery per ha. If the time from the sowing to the sprouting is excluded, the figures will show that the average daily maize yield here was more than a ton of verdure. Since during the first period after sprouting the maize plants grew slower and during the second period much faster, we have the right to consider that the daily growth of the second period was about 2-3 tons of greenery per ha.

I must confess that before looking through the above booklet I, a scientific worker, not only did not know of such superb increases of valuable fodder but never even conceived them.

The task set by the Communist Party—to effect a sharp increase in the production of maize—has provided biologists and scientific agriculturists with an abundance of work along new avenues, work of immense theoretical interest and at the same time of paramount practical importance.

Leningrad is the site of numerous biological and agricultural research institutions. It is a matter of prime urgency for these institutions to revise their plans and to concentrate on a comprehensive solution of the problems of introducing maize into the north-western districts of the Soviet Union, on selecting the varieties that yield the biggest crops, and on starting the production of these varieties.

Now, after the Plenary Session's instructions have been received, it is necessary for all research institutions to re-

organize their work with all possible speed and contribute their bit to the rendering of effective scientific assistance to the collective and state farms determined to grow maize the best way.

Even in the Komi A.S.S.R., i.e., the region almost furthest north in our country, it has been shown by the experience of the collective and state farms that it is possible to obtain from 400 to 600 and even 800 centners of greenery per ha. And in 1954 they still sowed haphazard varieties. Yet it is well known that many forms (varieties) of maize greatly differ from one another. For instance, maize varieties differ in length of vegetative period not less than winter from spring wheat, the only distinction being that winter wheat differs from spring wheat in the length of the first phase, the stage of vernalization, while maize varieties differ in the second, in the photo stage.

Biologists know that if southern late-ripening maize forms (varieties), which require comparatively short days and long nights to pass through the photo stage, are crossed with ultra-early-ripening varieties, such as, for instance, the Siberian varieties—with Beloyaroye Psheno, Slavgorod, or early-ripeners from Volga districts, for instance, with Bezenchuk varieties and others—the mixed breeds (first-generation hybrids) obtained in the northern districts are almost as early-ripening as the early-ripeners indicated, and at the same time have as powerfully developed stalks, cobs and leaves as the southern late-ripeners.

It is a matter of honour for the All-Union Institute of Plant-Growing, which has at its disposal a large maize seed collection from all districts, to take an active part in the urgent work of selecting pairs for maize crossing. The purpose of this work is to ascertain for the various districts of the north-western zone and likewise for the central zone of the Soviet Union the best combinations, the best parental pairs for obtaining hybrid maize. Naturally the All-Union

Institute of Plant-Growing should not be the only one participating in this work.

The All-Union Institute of Agricultural Microbiology is also faced with a responsible task. On the collective and state farms of all the districts of the U.S.S.R., including, of course, the districts of the north-west, a considerable quantity of maize will be preserved this very year by means of siloing in the milk-wax stage. The green maize stalks and leaves will be used by the farms to silo still more greenery. The preservation of both the grain and the greenery of the maize plant by siloing is a microbiological process. Hence the rendering of scientific assistance by the Institute of Agricultural Microbiology to the collective and state farms is a matter of cardinal importance.

The institute must carefully study all questions related to siloing and work out this problem in conjunction with the workers of the agricultural agencies. It is imperative that already this year a considerable number of collective and state farms, and not only of the north-western zone but also of other zones of our country, should be able to make use of the institute's aid in siloing maize cobs and greenery. Much to the credit of the Institute of Microbiology, its achievements in the preparation of definite microbiological ferments essential for the production of good silo are quite significant.

It is highly desirable that the greatest possible number of collective and state farms should use these ferments even during the current year. The use of lactic acid ferments in siloing maize cobs and greenery will not only promote the production of better silage—which in itself is of sufficient moment—but will furthermore be useful because in many cases it prevents the development of putrescent microflora in the mashed vegetative mass.

A number of other extremely important problems could be singled out as requiring urgent solution by the scientific staffs of the Leningrad institutions.

On one of these problems, perhaps the main one, the prob-

lem of fertilization, I shall speak quite in detail later on. For the present I shall confine myself to the fact that many fields in the north-western districts need to have their surplus water drained off. A number of agricultural areas there have literally become bogs, while others, not yet bogged, become supersaturated with water that has no outlet when precipitation is too heavy. It is therefore urgently necessary that at least the simplest ameliorative measures be taken, such as drainage by furrows and ditches.

Likewise very important are appropriate agrotechnical methods of rearing agricultural plants. Of particular importance is the square-pocket sowing of potatoes and maize. This method of sowing makes it possible with the least expenditure of labour to cultivate a field mechanically in two directions, i.e., lengthwise and crosswise, hence to practise weed control. However, it is highly essential and has been known for a long time that in these districts, at least in sections where water easily stagnates, row crops should be raised on the crests so as to let the water run down into the furrows. That is why it is necessary in the north-western districts to combine these two agrotechnical methods, namely, square-pocket sowing and consequently tractor- or horse-drawn cultivation in two directions (lengthwise and crosswise), and the growing of row crops on the crests. At first glance these methods seem incompatible. In actual fact it is impossible to cultivate in both directions—lengthwise and crosswise—and at the same time have crests. But I believe it possible even then to sow or plant maize and potatoes by the square-pocket method. Before the potato and maize sprouts appear and immediately after they appear one must combat the young weed sprouts and the soil crust by harrowing the crops, and when it is no longer possible to harrow, the sown area must be cultivated at least twice, lengthwise and crosswise, at not too long intervals, so that the weeds will not be allowed to start growing. As soon as tiny weed sprouts, barely perceptible to the eye, make their appearance, the land

must be cultivated. This is to be followed by cultivation with hilling implements, but now only in one direction, lengthwise, in order, as practical agriculturists say, to "grow" crests.

I think my remarks apply not only to potatoes, whose exacting hilling demands are generally known. It seems to me that in the north-western districts hilling is a useful thing for maize too. In the first place banked-up maize plants will not suffer from surplus moisture, as the water will run down from the crests into the furrows. In the second place, maize after hilling quickly forms a supplementary powerful root system from the lower node of the stalk. When the maize rises to a height that makes it impossible to work in the field with a tractor, further cultivation or hilling has to be done by horse-drawn implements.

In the north-western zone many fields are not only boggy but overgrown with bushes. With the powerful technical equipment possessed by our machine-and-tractor stations and state farms, the stubbing of bushes presents no great difficulty. But it requires machinery and a lot of fuel.

I say this in order to show that here too the research staffs of the Leningrad institutions may be of considerable assistance to the machine-and-tractor stations and state farms in the application of economic methods of cleaning the fields. The reference is here to chemical means (herbicides) of combating bushes in the fields. This will greatly accelerate the destruction of bushes that obstruct the fields and diminish expenditures for that purpose. The All-Union Institute for the Protection of Plants, which has had some experience of the use of herbicides, as well as a number of other research institutions acquainted with this problem, should get down to working out suitable measures and rendering immediate assistance to agricultural practitioners.

It must be said, however, that not infrequently scientific

workers desirous of helping production do not know what exactly they can do about it, to what they can apply their knowledge. That is the reason I am now turning to the managers of production, to the officials in the ministries and the regional agricultural agencies, to the officials in the machine-and-tractor stations and to the agronomists, asking them for help. We earnestly request that they should not only enhance the demands they make upon their workers in the sciences of biology and agriculture, but that they themselves should delve more deeply into the problems involved and acquaint themselves more thoroughly with the work of the research institutions and that of their individual staff members.

Whoever knows the weak spots in our production will find it easier and simpler to get from science precisely the knowledge that will facilitate the elimination of these weak spots. It cannot be that people in possession of scientific knowledge, including knowledge of the biological laws discovered by science, should be unable in any concrete situation to render the assistance which production stands in need of.

Everything depends here on one's mastery of the subject, one's skilful utilization of one's knowledge, one's ability to apply and combine into a single complex one's specific knowledge of various aspects of theory and practice.

I now pass on to the problem of field fertilization. We all know that good crops are impossible on podzol soil, particularly in the districts of the north-west, unless fertilizer is used. One might think that once this is generally known, there would be no need to say anything more on the subject. None the less, in recent years and especially last year, I took advantage of almost every occasion to speak about fertilization.

First of all I must state—and this is my deep conviction —that the science of fertilization, the theory of the soil nutrition of plants, is the most backward department of biological science. Moreover, the fertilization of fields, or,

to be more exact, the nourishing of plants by means of the roots, of the soil, has so far been hardly considered as a biological process.

Yet the soil nutrition, the root nutrition of plants is inherently a problem of scientific agriculture. And the science of agriculture, according to my lights, is a science that treats at bottom of soil micro-organisms.

If one takes this point of view in analysing certain agrotechnical methods of tilling the soil, for instance, ploughing, cultivation, harrowing, compacting (rolling) the soil, draining off superfluous water, introduction of organic and limestone fertilizers, etc., one readily arrives at the conclusion that each of these methods aims at creating the life conditions of beneficial soil micro-organisms. We apply this term to micro-organisms whose vital activity promotes the proper root nutrition, i.e., soil nutrition of the plants concerned.

The data furnished by the various departments of materialist biology led us to conclude that the root nutrition of plants from the soil is a process that goes on by the agency of suitable soil micro-organisms. Hence the creation with the assistance of particular agrotechnical methods, including the application of various fertilizers to the soil, of the conditions necessary to sustain the life of useful micro-organisms and the suppression of the vital activity of harmful micro-organisms amounts in fact to the creation of the conditions of the soil nutrition of plants.

Thus we hold that plants take in food through the roots by the agency of soil micro-organisms, and that different species of agricultural plants derive their food from the soil by the agency of different micro-organisms specific for the plant species in question.

It may not seem worth while for the present large and important conference of agricultural workers of the north-western districts to engage in an analysis of such primarily theoretical questions, for the conference is discussing concrete problems of carrying into execution the highly signifi-

cant decisions of the January Plenary Session of the C.C., C.P.S.U. One may be inclined to believe that such purely theoretical issues—particularly an issue like the root nutrition of plants, which is still considered controversial—had better be taken up at special meetings devoted to theoretical problems. But it is my conviction that precisely conferences like the present one should discuss, at least briefly, the theory of the root nutrition of plants. Further theoretical debates cannot add anything that will help to solve the problem. Only practice will furnish its solution. I am certain that this issue will be settled when not only workers in the biological and agricultural sciences but also thousands of agronomists and millions of collective farmers will make a concerted effort to settle it. Those quite numerous scientific workers who specialize in problems of fertilization and pointlessly object to the conception we have propounded of the root, i.e., soil nutrition of plants and in consequence are also averse to our proposed method of fertilization, will be compelled, under pressure of the practical results achieved, to change their views.

The role of the micro-organisms in the normal soil, i.e., root, nutrition of plants consists in this: Chemical elements of the soil and air that cannot be assimilated by the plant roots become assimilable through the instrumentality of enzymes secreted by microbes.

I have said repeatedly in my speeches and writings that suitable soil micro-organisms play the same physiological part in the root nutrition of plants as the digestive tract in animals. In order not to take up too much time with this question I shall quote only one example, which, I believe, well illustrates the part micro-organisms play in the root nutrition of plants.

On some of the fields around Moscow and in your districts, too, one can see masses of newly-dug peat (procured in winter), piled up in some places at the rate of 100 tons a hectare. Of course, there are not many sites where such huge quantities of peat have been introduced

but in a number of cases peat in such doses is applied every year. Not only every agronomist but everyone who has the slightest smattering of field fertilization knows that the application per ha. of 100 tons and more of peat newly dug in winter will effect but a small increase in the yield of a crop which will be sown in spring in a section fertilized as above described. At the same time all agricultural workers know that 15-20 tons of such freshly won peat mixed with at least 3-5 tons of manure will turn in 3-4 weeks into a good fertilizer worth its weight in the best manure. As we know, 15-20 tons of peat in which micro-organisms beneficial to agricultural plants have multiplied (they are introduced into the peat with the manure) have a considerably better effect on the yield of any agricultural crop than the introduction into the soil of 100 tons and more of freshly dug peat not infected with beneficial micro-organisms.

Can it be that this illustration, universally known to practical agriculturists, means nothing and teaches nothing to those scientific workers who categorically reject our conception of the root nutrition of plants and simultaneously reject the conclusions drawn from it, i.e., the suggestions we have worked out on how fields should be fertilized? I am sure that everybody sitting here knows about our fertilization proposals, usually referred to as the "small-dose fertilization method." As was said above, the point here is not the small doses, not the quantities applied. The method we suggest consists in creating in the soil the conditions necessary for the development of beneficial soil micro-organisms, i.e., of those micro-organisms by whose agency the roots of a given plant species derive their food from the soil.

The numerous experiments performed at our suggestion by research institutions as well as collective and state farms showed that the application on organic-phosphoric-limestone fertilizer mixtures in quantities of 3-5 tons per ha. worked in not deeply and not by plough but by culti-

vator before sowing has the same yield-raising effect on any crop as the introduction of 20-30 tons of good manure per ha. A dressing of 3-5 centners of limestone materials (humus, manure or peat steeped in liquid manure) has more effect on acidic soil than the application to such soils of 30-50 centners of clean limestone materials without organic matter. In other words, organic and limestone fertilizers taken in doses 5-10 times smaller, not separately, however, but mixed with organic-phosphoric-limestone dressing, produce the same yield-raising results as the so-called full-dose fertilizers, i.e., 20-40 tons of manure and 30-50 and more centners of limestone materials per ha. of acidic soil.

In the north-western zone, as in all districts where there are acidic podzol soils, the introduction of limestone into the soil is an extremely important problem. All scientific and practical workers are aware of the fact that after the introduction of such doses of limestone materials as science recommended hitherto, namely, 30-50 centners per ha., only clover shows substantial increases in crop yields. All other crops, if sown immediately after the indicated doses of lime have been introduced, raise the yield but slightly, and in the case of flax and potatoes, for example, not infrequently lower the quality of the crop.

Consequently, liming as recommended hitherto by scientific workers, while beneficial, is very costly because of the required introduction of 30-50 centners of limestone materials per ha., and furthermore has a directly favourable effect only on clover.

But if as little as one-tenth of the above limestone material, no more than 3-5 centners per ha., is introduced into the soil, but mixed with 2-3 tons of organic fertilizer, and this mixture is worked into the soil not by plough, that is to say, not deeply, but by cultivator during the pre-sowing cultivation, all crops, including flax and potatoes, sown in fields thus fertilized will exhibit increased yields.

It is of vital importance to add phosphoric fertilizer—

superphosphate or ground phosphorite—to the above organic-limestone mixture.

In the north-western zone, particularly in Leningrad Region, and also in the Estonian S.S.R., there are millions of tons of shale ash. Leningrad Region has hundreds of thousands of tons of so-called belite meal (industrial waste). These two fertilizer materials of exceptional value to the north-western zone merit special mention.

Experiments at research institutions show that the application of shale ash, and particularly of belite meal, to acidic podzol soil is much more effective than such limestone materials as ground limestone, marl, etc.

Can one stand idly by on seeing or even only knowing that there are millions of tons of shale, combustible ash and hundreds of thousands of tons of belite meal available, but neither of them is utilized to increase crop yields? If skilfully applied in doses of 3-5 centners per ha. mixed with at least a small quantity of organic fertilizer, shale ash and belite meal may be no less effective than superphosphate applied in the same doses!

This, of course, does not mean that shale ash or belite meal can replace phosphorus.

These materials are industrial waste products, refuse. But they are very valuable for fertilizing acidic soils, yet lie about unused. Of course, if a similar quantity of unallocated ready superphosphate were to be had, no one would ever doubt the expediency of hauling this fertilizer to the fields that are in need of it. And if that question is now under debate with regard to combustible shale ash and belite meal, of which agriculture makes almost no use at all, the only explanation I think is ignorance of the effective methods of applying these materials.

Scientific workers who are working on the problem of liming still recommend that both belite meal and shale ash should be introduced into the soil in doses of 3-6 tons and more per ha. without mixing them with organic matter. Such recommendations naturally do little to spread the ap-

plication of this valuable fertilizing material. But once collective farmers, and state-farm and MTS workers, learn from their own experience that 3-5 centners of belite meal and shale ash mixed with at least 2-3 tons of manure, or if there is not enough manure, with peat steeped in liquid manure, have a good effect on any crop if introduced into the soil, then undoubtedly many millions of tons of belite meal and shale ash will be consumed as fertilizers.

The same applies to organic fertilizers. When agricultural workers are actually convinced that 3-5 tons (the more, the better) of organic fertilizer mixed with 3-5 centners of limestone material (shale ash, belite meal, etc.) plus 2 centners of ground phosphorite and at least 0.5 centners of superphosphate have the same yield-raising effect as 20-40 tons of manure and 30-50 centners of limestone material, then the amount of procured and prepared organic fertilizers will at least double or treble on our farms. This is indisputable.

A few words on peat for litters. Top-layer peat makes excellent material for cattle bedding.

I should like to remind the Ministries of Agriculture and State Farms of the U.S.S.R. of the need to organize the procurement and drying, in other words, the preparation of good litter peat. The existing enterprises must be enlarged and additional ones put up for that purpose.

Good litter peat greatly improves the conditions of keeping cattle. Moreover, when sufficient litter peat is used the amount of manure doubles and trebles and its quality gets much better.

Briefly on the methods of applying the organic-phosphoric-limestone mixtures we recommend. When hand-sowing maize by the square-pocket method, a handful—200-300 gm.—of the organic-phosphoric-limestone mixture must be deposited in each pocket. Here the dose per ha. is about 5-6 tons.

The fertilizer mixture is prepared from the following constituents in approximately the following quantities: 4-5 tons

(and more if possible) of humus, rotten manure or peat-manure compost, or peat suitable for fertilization but always drenched with liquid manure; phosphoric fertilizers: 2 centners of ground phosphorite and 1 or at least 0.5 centner of powdered superphosphate; limestone fertilizers: 3-5 centners of belite meal or shale ash, or other limestone materials (ground limestone, marl, limestone tufa). All these components must be thoroughly mixed and, as said above, introduced into the maize pockets, a handful into each. If the maize is to be sown by machine, the said dose of organic-phosphoric-limestone mixture should be evenly spread over the field and covered up by the pre-sowing cultivation.

A few suggestions on potato-field fertilization. In most cases the potatoes will be planted by four-row potato planters. We recommend that after cultivating the field for the last time before the sowing and before machine-planting the potatoes, 4-6 tons of the mixture per ha. should be broadcast and not covered up in the soil. When planting the disks of the machine take off a thin slice of the upper layer of the soil between the rows and rake it up together with the fertilizers into a ridge over the tubers. The fertilizer broadcast over the surface of the soil before the planting will therefore be mixed with the top layer of the soil and transferred to the crest nearest to the planted tubers. I believe this way of fertilizing will show good results in the north-western districts.

If for any reason no fertilizer has been introduced before or during the sowing of maize or potatoes (which is to be avoided), one must apply the organic-phosphoric-limestone mixture after the sowing, before sprouts appear, covering it up by means of a harrow. It is useful to introduce the mixture into maize fields also in the shape of extra feeding before cultivation. If there is not enough superphosphate or ground phosphorite for all the fields of the farm, it is advisable to introduce a double portion of organic and limestone mixture into the maize fields.

When the organic-phosphoric-limestone mixture is inserted into potato pockets, only shale ash or belite meal should be taken of the limestone materials. Other limestone materials are apt to give the tubers the scab.

No doubt all scientific workers will render the collective and state farms maximum assistance in the execution of the historic decisions of the January Plenary Session of the Central Committee of our Party.

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SOIL NUTRITION OF PLANTS*

With the progress of Michurinist biological science, which discovered a number of basic laws of development of the organic world, problems concerning the theory of the soil nutrition of plants are being examined in a new light. For the last few years the Lenin Academy of Agricultural Sciences of the U.S.S.R. has been conducting research into these problems and the biological laws governing this process are being formulated. We stress the point that what is being discovered is the biological laws governing the soil nutrition of plants. At the same time it is perfectly clear that without the accumulation of the factual material necessitated by the development of the chemical and physical sciences it would have been impossible to establish the biological laws of the soil nutrition of plants. Vital processes take place in living bodies on the basis of biological laws by the agency of chemical and physical transformations.

Knowledge of these laws of plant nutrition enables scientific workers to render practitioners more effective assistance in field fertilization problems.

Practice shows that to cultivate land, i.e., turn soils of low fertility into soils of high fertility, is something that can

* A paper read at the International Seminar of Students of Higher Agricultural Institutions held on June 22, 1955 in Moscow.

be done over large areas only by annually obtaining rich crops on these soils. This looks like a vicious circle. Soils of low fertility produce small crops and can be converted into soils of high fertility only by obtaining big crops from these poor soils. What is the way out?

In most cases little organic matter, little humus is contained in soils of low fertility, in uncultivated soils, such as podzol, loamy, and particularly sandy soils. These soils, as everyone knows, respond well to the application of organic fertilizer. Cultivated podzol soil contains considerably more organic matter, humus. Cultivation of podzol soil consists in the main precisely in saturating it with organic substances so as to increase its humus content. People with practical experience have long known that fertilizing poor podzol soil means putting 30-40 tons of good manure into it per ha. It would be still better if mineral fertilizers could be introduced in addition to the organic fertilizers (manure): per ha. 2-3 centners of superphosphate or 3-5 and even more centners of ground phosphorite, or 1-1.5 centners of potassium fertilizer. When podzol soils are highly acidic it is advisable to introduce 30-50 centners of limestone materials per ha. to lower the acidity. The use of the above quantities of fertilizers and limestone materials ensures good crops on poor podzol soils of high acidity. The considerable yield improvement resulting from the introduction of fertilizer into podzol soil of low fertility was and is explained by most scientists as follows: the fertilizers introduced have become food for the plants and the lime has lowered the soil acidity harmful to plants.

We consider such a seemingly obvious explanation not only one-sided but in many cases even wrong. To prove this we must analyze, at least briefly, what unfertile and fertile soils really are.

A number of wild tree species grow well on uncultivated podzol soils that are of low fertility with regard to many agricultural plants. Hence the concept "fertile and unfertile" soils is a concrete one. A soil unsuitable for certain plant

species may be good for others. At the same time it can safely be asserted that certain laws of soil nutrition are of general application to all plants. If these laws are explored further, the differences between the soil nutrition of the different biological plant species will become clearer. Similarly, the laws which govern the process of nutrition and are *general* for all plants can be ascertained by studying the specific, particular forms of this process, the forms peculiar to individual plant species.

The soil nutrition of plants is a biological process. But every biological process goes on by means of chemical changes in substances and of physical, mechanical motions that take place in accordance with certain chemical and physical laws. Therefore the study of biological processes must not be divorced from that of chemical changes and physical motions; nor may biological processes be reduced to chemical and physical ones. Moreover, in the usual development of organisms (development without change of heredity), biological laws determine the specific features of the chemical and physical interconnections themselves within the organism itself as well as with the surrounding environment. But when organisms develop under conditions they are more or less unaccustomed to, certain new chemical substances or old substances with new chemical interconnections may join in the biological process. It is the conversion of these new substances, or old substances in new chemical interconnections, from non-living into living matter that brings into being new biological properties, new biological laws.

In building a living body the starting point is matter taken from non-living nature. The living evolving from the non-living acquires properties which, while radically differentiating it from the non-living, at the same time necessarily preserve its nexus with the non-living from which it sprang. It is a characteristic property of a living body to enter of necessity into a *unity* with the non-living matter from which it took shape at some time in the past. This property of the living body is assimilation and dissimilation,

i.e., the nutrition of the living body in its scientific conception, and it is this that determines the growth and propagating faculty of the members of a species.

All living nature consists of separate forms (species). All species—whether animals, plants or microbes—are interconnected with one another and with non-living nature, the original source of living nature. Discovering the natural interconnections of species both with one another and with the conditions of non-living nature is precisely what is meant by discovering biological laws.

It has been proved scientifically that soil is the result of the interaction of micro-organisms, plants and animals with the bedrock and atmospheric elements. As long as there was no life on earth there were no such natural bodies as those called soils, and there could not have been. Hence each soil has its history: its origin and development. The study of these processes constitutes the department of science called soil science.

If the vegetable forms are singled out from the entire gamut of the organic world, it may be said that as the soil, so the vegetation, and, vice versa, as the vegetation, so the soil. Thus, under natural conditions, on boggy soil bog plants grow; on podzol soil, forest trees and bushes; on turfy podzol and steppe chernozems, grassy meadow and steppe vegetation. The quality of the soil determines the kinds of plants, and the kinds of plants determine the quality of the soil. It must be remembered that the species and varieties of agricultural plants differ in their natural demands upon the soil from the soil demands of the various wild species. We have already mentioned that agricultural plants grow meagrely or not at all on acidic podzol soils unless organic fertilizer is introduced, while wild ligneous species, for instance the birch, pine and other trees, grow fine on such soils.

Agricultural plants require that the soil should be tilled, i.e., put into a crumbly condition, whereas wild plants—forest or meadow—do well without tillage.

Agrochemists are fully aware that there is insufficient phosphoric and particularly nitrogenous nutrition for agricultural plants in uncultivated podzol soils. At the same time the same soil contains all elements of soil nutrition, including nitrogen nutrients, in sufficient quantity for ligneous species like the birch. Who does not know that on rocky mountains, where agricultural plants will not grow, majestic forests are a not infrequent sight. In scientific agronomic circles it is held that gaseous nitrogen can be utilized only by leguminous and some other plants which fix atmospheric nitrogen through nodule bacteria. In such event where does fixed nitrogen come from, where does nitrogenous food come from on rocky mountains for tree species having no nodule bacteria?

An answer to these and similar questions can be given only after discovering the biological laws of the soil nutrition of plants. Knowledge of these laws enables one by various agrotechnical methods to create the conditions for the proper nutrition of agricultural plants even on soils of low fertility, thereby converting them into fertile soils.

Agronomic science holds, on good grounds, that the principal potential plant-food reserves in the soil are its organic substances (mainly humus). This food supply, consisting of organic substances not directly assimilable by plants, is gradually transformed by various micro-organisms into compounds that plant roots can assimilate. As a result of the mineralization of organic substances contained in the soil and of the consumption of mineral salts by plants whose crops are taken from the field, the supply of organic matter in the soil diminishes. It is therefore believed that the virgin chernozem soils rich in organic substances get poorer with every crop, become less fertile, unless the nourishment taken from the land by the plants is returned to it in the shape of fertilizers. Soil rich in humus is considered more fertile than soil containing little humus. The cultivation of podzol soils consists, as a rule, in saturating them with organic matter, i.e., in the final analysis, with humus.

The so-called theory of "taking away and returning back" with its variants was built up on the premise that plants take food from the soil by means of their roots; it was built up because of the lack of knowledge of the laws of soil development and of the laws of the root nutrition of plants. Many agrochemists cling to this theory to this day in many respects. Being confined within the narrow frame of their speciality all they see in the processes of soil nutrition is their chemical aspect. They are ignorant of the biological interconnections, the links in the biological chain, the metabolic circuit on the basis of which chemical changes take place in the soil—the transformation of substances that plants cannot assimilate into substances they can.

The soil science of V. R. Williams, i.e., his teaching of the origin and development of the soil, is, we believe, in the main correct. This teaching led to the discovery of the general laws of development of the soil in free nature. In "free nature," we stress, and not in agricultural practice. By this we do not want to say that biological laws, in the case under discussion the laws of the root nutrition of plants, are one thing in free nature and another thing in agricultural practice. The same identical biological laws operate in free nature and in agricultural practice. If we know them we can use them to transform soils of low fertility into fertile soils without waiting for the proper conditions to take shape themselves in the natural course of events.

It may here be repeated that for ages practical farmers have known the immense favourable effect of the saturation of soils with organic matter—humus. Agricultural practice has also long known that on soil poor in humus, for instance on uncultivated podzols, it is as a rule impossible to obtain good yields without using big doses of organic fertilizer. It therefore seems to me that the theory of the soil nutrition of plants should reveal the essential reason for the incongruity of the still often repeated agronomic assertion—that the principal mineral food reserves in the soil for agricultural plants exist only in the form of organic

substances—with the assertion that for a number of wild plant species the mineral food reserves are not to be found in organic compounds.

It follows that in free nature mineral nutrition for the building up of plant organisms is obtained from inorganic matter, but in agricultural practice mineral nutrition for the building up of plant organisms is said to be obtained from organic bodies (after their mineralization).

It has been shown by agrochemistry that for the building up of the bodies of their organisms all plant species require the presence in the soil of the same main chemical ash elements, such as phosphorus, potassium, calcium, magnesium, iron, sulphur and many others called micro-elements. Plants also obtain nitrogenous food from the soil. This has been plainly demonstrated by experiments with water cultures: if plants of various species are reared in water cultures it can readily be observed that almost all of them require about the same composition of nutritive mineral salts. The difference in the chemical composition of the ash elements of the various species of plants is more quantitative than qualitative. But under field conditions there is a sharp difference between the relation of wild plant species and cultivated species to soil fertility. In acidic podzol soil poor in humus, cultivated plant species find little nutriment and some none at all. But many wild plants, both grassy and woody, may fare well on the same soil. They find sufficient food there.

Proceeding on the erroneous assumption that the main mineral food reserves of agricultural plants are contained in the soil only in organic compounds, scientists are still of the opinion that to obtain rich crops on soil poor in organic matter it is necessary to administer big doses of organic fertilizers and of mineral fertilizers in forms assimilable by the plants, as well as of limestone fertilizers. The application of small doses of these fertilizers to such soils is considered insufficient for getting good crops. Yet both wild and cultivated plants take from the soil the same water-soluble compounds of chemical elements, regardless of their origin,

i.e., regardless of whether they are formed from compounds of chemical elements of the soil or atmosphere, or in the process of mineralization of the organic substances, or of whether they are introduced into the soil in the form of factory-made water-soluble fertilizers. The only thing required is that the chemical elements wanted as nourishment for the plants should be in the form of oxides.

Taking the above as the starting point one may assume that in soil of low fertility, for instance, in humus-poor sandy loam or sandy soil, on which pine-trees grow well but agricultural plants will not grow unless organic fertilizer has been applied, potential food may be found also for cultivated plants. But for cultivated plants this potential food does not become transformed into actual food that the plants can assimilate, i.e., into the chemical compounds required for the root nutrition of plants, while for wild plants, in our illustration pine-trees, the same potential food is converted in the same soils into compounds of the chemical elements needed for the root nutrition of plants.

We know from agrochemistry that water-soluble mineral food is the same for all species of plants. When we find out the reason why there is a difference between the relation of wild plants to potential fertility and that of cultivated plants, it will be possible to convert potential into actual fertility also for cultivated plants and thereby to obtain big yields of all agricultural crops also on soils of low fertility. And high yields year after year of all agricultural crops, especially of perennial grasses, is the surest way of turning soils of low fertility into rich, fertile land.

THE ROLE OF MICRO-ORGANISMS IN THE SOIL NUTRITION OF PLANTS

Microbiology, particularly soil microbiology, is a new department of the science of biology. That is one of the reasons why the process of the soil nutrition of plants has to

this day not been properly coordinated in science with the vital activity of the soil microflora. The role of the micro-organisms in the soil nutrition of plants has been reduced, in the main, by science to the destruction, the mineralization of organic substances. The role of micro-organisms in the synthesis of organic matter from elements of inorganic nature has been almost wholly disregarded. Indeed. in free nature, in the complex biological process of transforming elements of inorganic nature into organic bodies of plants, numerous species of micro-organisms act as necessary (law-governed) links.

The factual material accumulated in the field of microbiology and the biological laws of development of the organic world discovered by Michurinist agronomic science necessarily lead to the following conclusions:

1. The fermentative activity of the corresponding soil micro-organisms forms an essential link in the normal natural process of the soil nutrition of plants.

By the agency of various ferments secreted by micro-organisms, water-insoluble chemical compounds of the soil and atmospheric elements, both unassimilable by plants, turn into water-soluble compounds that plants can assimilate.

2. The roots of various species of plants are naturally interconnected with species of soil micro-organisms that are specific for these plants. This interconnection of plant species with their specific micro-organisms means that in the absence of these plants in the soil the micro-organisms corresponding to them cannot develop, and that without the vital activity of these micro-organisms these plants experience a shortage of assimilable food in the soil. In that case the soil is but slightly fertile for these plants. But if we evoke the vital activity of the micro-organisms corresponding to the plants sown, the plant nutrition improves and the soil ceases to be of low fertility for them. The efficacy of soil fertility, i.e., whether it nourishes agricultural plants well or ill, depends mainly on the vital activity of an intri-

cate interconnected chain of species of soil micro-organisms beneficial to the plants in question. In some cases the temporarily bad growth of plants on a particular soil is due to the lack in it of certain soil micro-organisms specific for these plants. Thus it is possible to observe the absence in the soil of nodule bacteria for particular leguminous species. But, as experience shows, such absence of the corresponding micro-organisms is temporary. Sooner or later, in two or three months, for the duration of one vegetative period, or during two vegetative periods, corresponding nodule bacteria appear in this particular soil, in consequence of which the nutrition, and therefore also the growth, of these legumes improves considerably.

Where could these particular species of micro-organisms, absent before and now present in the soil, come from? They could either have been carried into the soil or be the result of the conversion of some micro-organismal species into other such species. Michurin biologists have firmly established the fact in several cases that certain species of plants are converted into other species. Microbiologists have established such facts also in the world of micro-organisms. The transformation, or rather generation, by some plant or microbe species, of other species takes place under the influence of conditions of life unsuitable to the organisms of the species in question. Under the influence of such conditions, sooner or later, in two or more generations of these organisms, the latter generate other, new specific forms more suitable to the existing conditions of the external environment.

Michurinist biology (department of genetics) long ago established the fact that a change in heredity is effected only by a change in the type of assimilation and dissimilation. A change in heredity always ensues in accordance with, and is adequate to, the influence of the assimilable conditions of the external environment.

On this basis one will readily understand that if the roots of plants grown from, say, clover or lupine seeds sown for

the first time in that section appear in a certain soil, then, as was said above, sooner or later nodule bacteria of clover appear on clover roots and of lupine on lupine roots. The soil further contains a variety of other bacteria, some of which, due to the action of the root secretions of the said plants, may transform themselves into bacteria species appropriate for these plants.

It is not advantageous for practical farming to await this natural course of events, in the present instance, to await the appearance of the nodule bacteria for the legumes. Therefore legume seeds are inoculated before sowing with nodule bacteria specific for that particular species of legumes. The same thing is done when sowing many tree and bush species in woodless districts. Micro-organisms (mycorhiza) suitable for these tree and bush species are introduced together with the seeds into the soil.

Nowadays a whole series of other bacterial fertilizers is known, for instance, azotobacterine, phosphorobacterine, silicate bacteria and a complex bacterial fertilizer (AMB). The number of such fertilizers is certain to increase considerably.

Perhaps not all these bacterial fertilizers are directly connected with the roots of agricultural plants. But they certainly are connected with the complicated microbiological chain partaking in the process of root nutrition of the plant species in question. This is the only explanation of the cases of improvement of plant nutrition as a result of the introduction into the soil of some particular bacterial fertilizer.

But practical farmers likewise know that on acidic podzol soils of low fertility the introduction of bacterial fertilizers does not improve the nourishment of plants. This can easily be demonstrated, for instance, by the example of clover. Clover grows badly on such soil even when the nodule bacteria it needs are introduced into the soil together with the seed. The explanation offered is also well known. It amounts to about the following: the plants do not develop well because the soil is poor, devoid of organic matter—the source of

mineral alimentation for agricultural plants. Besides, if the acidity of the soil is high, this also has an injurious effect on legumes and other agricultural plants.

In order to obtain good yields it is therefore recommended to dress such soils with big doses of organic fertilizer (30-40 tons per ha.) and to introduce water-soluble mineral fertilizers. To lower soil acidity agriculturists are advised to apply 30-50 centners of limestone fertilizer per ha.

But in actual fact plants develop badly in such soils, as has already been stated, for the sole reason that the latter lack the conditions necessary for the vital activity of the soil microflora essential and beneficial to agricultural plants, even when this microflora is introduced into the soil artificially. If these conditions are created, the beneficial soil microflora develops and poor soil becomes fertile, i.e., will contain sufficient nutriment for agricultural plants.

We have already mentioned that different plant species or groups of closely related species have different suitable soil micro-organisms. This implies that without a root system, without the secretions of the root system of the plant species in question, the soil micro-organisms corresponding to that species cannot live normally. But this does not at all mean that the normal vital activity of these soil micro-organisms requires only the existence of the roots of the plants concerned or their root secretions.

Michurinist biological science knows that every organism requires for its normal vital activity a complex of conditions corresponding to its nature (heredity), including the necessary interconnections with other phenomena of living and non-living nature. It is therefore clear that micro-organisms like clover nodule bacteria, for which it is vitally necessary to be connected with clover roots, in addition to other conditions, require interconnections with other species of soil micro-organisms, or rather with the products obtained as a result of the vital activity of other soil micro-organisms, as well as with elements of non-living nature (mineral elements of the soil, sub-soil and atmospheric elements).

All scientific data testify to the fact that the very intricate chain of interconnections of different groups of soil micro-organisms is connected at the one end or link with the root system of the plants and at the other end, the other links, with elements of non-living nature (bedrock, atmosphere).

The organic substances of the soil are needed least for the direct nutrition of the plants. They are necessary as nutrient elements for various soil micro-organisms, the products of whose vital activity form links in the general chain of a complicated biological process—the transformation of chemical compounds of the soil and of gaseous nitrogen, which cannot be assimilated by plants, into assimilable plant food.

Hence soil without organic matter is uncultivated soil little fit for the growing of agricultural plants. But, as we have already pointed out, this same uncultivated soil containing little humus suits many plant species growing wild. These species receive nutrition from the soil through the agency of another complex of soil micro-organisms. The soil micro-organisms of this complex can dispense with the dead organic matter (humus) essential to many micro-organisms beneficial for the nutrition of agricultural plants. The specific feature of the processes of the soil nutrition of various plant species, both wild and cultivated—the specific feature of the process of conversion in the soil of unassimilable chemical elements and their compounds into alimentation that the plant roots can assimilate consists in the fact that the complexes of the corresponding soil micro-organisms, directly or indirectly connected with the roots of the plants, are different.

The vital activity of most soil micro-organisms beneficial to agricultural plants requires the presence of organic matter in the soil. Different physiological groups of micro-organisms make use of organic substances of different complexity and composition. Cellulose bacteria require organic matter which contains cellulose, while micro-organisms which fix atmospheric nitrogen require organic matter

not in the form of cellulose but in the form of simpler soluble carbohydrates.

In order to enable cellulose bacteria to carry on the enzymic process of decomposing cellulose into water-soluble carbohydrates, these bacteria need several other nutritive elements, among them fixed nitrogen, phosphorus and potassium.

At the same time it must be borne in mind that in the case under discussion monosaccharides, for instance, as nutritive elements, are necessary to and used by cellulose bacteria as well as by bacteria fixing free nitrogen. But cellulose bacteria may, by means of their ferments, convert cellulose into sugars while the nitrogen-fixing bacteria must get the monosaccharides they require in a ready form, as they have no ferments that can fission cellulose. On the other hand, nitrogen as a nutrient element for cellulose bacteria must exist in fixed form, but for the nitrogen-fixing bacteria the presence of gaseous nitrogen is sufficient. By means of enzymes elaborated by nitrogen fixers, gaseous nitrogen is turned into fixed forms.

We have cited but one simple illustration of interconnection between two species of soil microbes. In free nature, however, the chain interconnections between the processes of the conversion of substances exceed in intricacy beyond all comparison the example adduced by us. All this makes it imperatively necessary that experiments of interest in this line should be performed.

Microbiologists have already made a number of such experiments.

The differences in the root secretions of different species of plants in their turn determine the differences in the transformation of unassimilable water-insoluble substances into assimilable ones and also the specific features of the composition of the root-zone microflora.

In the synthetic medium, in which cellulose is the sole source of carbon, fixed nitrogen exists only in insignificant quantities (traces), but where all the other necessary

elements are present, cellulose and nitrogen-fixing bacteria may be grown jointly. These species of micro-organisms do not, however, propagate separately in the medium indicated, since the cellulose bacteria in it would lack nitrogen and the nitrogen-fixing bacteria would be deprived of soluble carbohydrates and for that reason would also not grow. But if they are cultivated jointly in the above medium the cellulose bacteria will decompose and convert the cellulose into monosaccharides, which both the cellulose and the nitrogen-fixing bacteria need. In this medium the nitrogen-fixing bacteria will fix the gaseous nitrogen, which is likewise necessary as an element of nutrition for both the nitrogen-fixing and the cellulose bacteria. Therefore, if cultivated jointly, the cellulose and nitrogen-fixing bacteria will grow normally in the said media, whereas cultivated separately neither of these species can grow normally.

This experiment (it can easily be made in a simple laboratory) shows that an environment barren for either of two species of micro-organisms may turn into an environment ensuring normal life activity on the part of these species when they are cultivated together.

Let us try, in the light of the given illustration of the joint cultivation of cellulose and nitrogen-fixing bacteria in a synthetic medium, unfit (barren) for any species taken separately and fit (fertile) for their joint growth, to analyze a conventional example of growing agricultural plants on uncultivated barren or poor acidic podzol soil.

Let us sow seeds of winter wheat in the autumn at the time required on uncultivated poor acidic podzol. We know that under these conditions the wheat plants will grow badly. In comparatively severe winters such sown fields will often fare ill. The wheat yield on such soil will be meagre unless fertilizer is used. Everybody knows this and everybody seems to understand that the wheat grew badly for lack of sufficient nourishment in the acidic podzol soil. This is so indeed.

But why do the agricultural plants in this soil starve?

Agrochemists have hitherto tried to resolve this question by determining the food elements deficient in the soil but assimilable by the plants.

Chemical analyses have proved that in podzol soil plants, as a rule, receive an inadequate supply of water-soluble phosphoric and particularly nitrogenous nourishment. It seems to me that if such foods are lacking, they must obviously be introduced into the soil in assimilable forms.

In addition to that, agrochemistry has ascertained that that very soil in which no forms of phosphorus or nitrogenous foods assimilable by the plants exist may contain huge resources of unassimilable phosphoric nutriment, not to mention the unlimited reserves of atmospheric nitrogen not directly accessible to the plants.

The introduction into the soil of water-soluble deficient food elements assimilable by the roots of the plants improves the nutrition of the latter and increases their crop yield. This alone is considered so far the practical benefit derived from introducing various mineral fertilizers in forms suitable for plant assimilation. However, the biological process of converting forms of matter that plants cannot assimilate into assimilable forms has not yet been tackled by agrochemistry and could not have been properly tackled by that department of science, as the problem is not one of chemistry but of biology.

Mineral fertilizers, especially phosphoric—superphosphate—are, as we know, by far not utilized in full by plants. The so-called coefficient of phosphorus, superphosphate, utilization does not, as a rule, exceed 20-30 per cent. The remaining 70-80 per cent of water-soluble phosphoric compounds, of superphosphate, according to the data furnished by agrochemistry, turn in the soil into water-insoluble compounds, are combined by the soil, i.e., are converted into forms that cannot be assimilated by the plant roots or are assimilated by them with difficulty.

Agricultural practice long ago arrived at the conclusion that besides the application of mineral water-soluble

phosphoric compounds (superphosphate), of mineral nitrogenous and potassium fertilizers, one must also introduce into podzol soil organic fertilizers, which cannot be replaced by mineral fertilizers. Thus, the numerous data taken from practice show that the importance of organic fertilizers cannot be confined to their being reserves of mineral substances in these organic fertilizers, of direct nutriment absorbed by the roots of the plants. The main part organic fertilizer plays consists in something else. As practical agriculturists say, organic fertilizers revive dead soils, soils of low or no fertility, soils which to boot suffer from high acidity. It is self-understood that the so-called revitalization of such soil consists in the activization of the vital functioning of the beneficial soil microflora.

The biochemical activity of numerous interconnected species of micro-organisms (bacteria, fungi, actinomyces, etc.) is due to the ferments they elaborate.

Particular importance in the process of the soil nutrition of plants attaches to the ferments secreted by microbes into the surrounding environment, outside the particular microbe cell. The action of these ferments causes unassimilable forms of organic and inorganic substances to become assimilable both by the microbial cells of the particular species that elaborates the ferments in question and by many other species of micro-organisms and plants which lack the property of producing these ferments.

The composition of plant nutriments directly absorbed by the roots may include chemical compounds both suitable for consumption by the given species of micro-organisms and unsuitable for that purpose, being waste matter of the vital activity of the microbes, yet this waste is assimilable and even essential food for other micro-organismal species.

Let us return to the above illustration of sowing winter wheat in podzol soil of low or no fertility at all. The agrochemists assert that this soil did not have enough phosphorus and nitrogen, particularly the latter, for the plants in assimilable forms. Let us introduce into this soil immedi-

ately before the sowing a small quantity (1.5-2 tons per ha.) of organic matter—humus.

We must remember that two-thirds (about 70 per cent by weight) of the 1.5-2 tons of organic matter (humus) introduced was water. Consequently, only 5-7 centners of air-dry organic matter were applied. The incorporated humus contains cellulose and small quantities of phosphoric and nitrogenous compounds that can be assimilated by cellulose bacteria, and other substances they need. Under these conditions the cellulose bacteria begin their vital activity, as a result of which monosaccharides and other water-soluble carbohydrates appear in the soil. When water-soluble carbohydrates as well as phosphorus, calcium and other elements are present, nitrogen-fixing bacteria also begin their vital functioning. As a result the gaseous nitrogen in the soil is transformed into ammonia which will be transformed in its turn into various ammonium salts, nitric acid salts and other forms of fixed nitrogen. And the fixed forms of nitrogen become accessible not only to various micro-organisms but also to the root system of the plants.

Hence the nitrogen deficiency of plants is allayed also in the given instance and in other cases the plants' nitrogen food wants may even be completely satisfied. Gaseous nitrogen will be the original source of the nitrogen in this food.

So far mention has been made only of nitrogen. Simultaneously with the above processes of transforming unassimilable nitrogen into an assimilable form a fermentative process converting unassimilable forms of phosphorus, potassium and other elements into assimilable compounds may go on in the soil.

In this way both phosphorus and potassium deficiency may be diminished or altogether eliminated.

As a result soil of no or low fertility is converted by the mere application of a small quantity—5-7 centners—of air-dried humus into land producing much bigger yields of agricultural plants.

In the example we cited the organic fertilizer dose was

small—1.5-2 tons per ha. This fertilizer is not introduced as a food reserve for the plants. Such a trifling quantity cannot satisfy the food requirements of the plants. It serves only as nutriment for the many species of useful soil microbes. In other words, organic fertilizers are applied in our illustration to create the conditions necessary but deficient in the soil in question for instituting the normal complicated biological process of plant nutrition by converting, under the influence of micro-organisms existing in the soil, unassimilable chemical elements and their compounds and also atmospheric nitrogen which cannot be assimilated by plants into forms capable of being assimilated by plants, into plant food.

Microbiologists know that in the case of the vast majority of laboratory-cultured soil micro-organisms, it is essential to introduce certain forms of calcium and substances containing phosphorus into the culture medium besides certain carbohydrates (so-called energetic substances) and several mineral salts.

On this basis and in order to normalize the vital activity of beneficial soil microflora, the Lenin Academy of Agricultural Sciences has proposed that the so-called small doses of fertilizers consisting of organic-phosphoric-limestone mixtures should be introduced as a widespread experiment into acidic podzol soil. These doses are 5-10 times smaller than the doses usually recommended, at least as far as organic fertilizers and limestone materials are concerned.

The experiments show that the increase in yield and the improvement in soil cultivation due to the above fertilizer doses are about the same as those obtained from the usual doses of organic fertilizer and limestone materials.

RESULTS OF EXPERIMENTS

The application of superphosphate mixed with a small quantity of organic fertilizers at the Academy's experimental farm in Gorki Leninskiye with the fertilizer worked in

only a little below the surface, greatly increases the efficacy of the superphosphate in comparison with its application unmixed (100-200 per cent).

The extensive experimentation conducted by research institutions and the production experiments of collective and state farms with the introduction of superphosphate mixed with small quantities of organic fertilizers into different soils also confirm as a rule the advisability of using such fertilizer mixtures.

The good effect of superphosphate mixed with small quantities of organic fertilizer can be explained in part by the fact that water-soluble phosphoric fertilizers change in the soil to a smaller extent into water-insoluble compounds difficult for plants to assimilate, the chief explanation being that such mixtures considerably intensify the vital activity of the useful soil microflora.

The question naturally arose of the expediency of adding small doses of lime-containing materials, e.g., ground limestone, ground dolomite, marl, etc., to the organic-phosphoric mixture, at least for acidic soils.

In the autumn of 1952, in the fields of the Gorki Leninskiye experimental farm of the Lenin Academy of Agricultural Sciences of the U.S.S.R., Academician A. A. Avakyan started an experiment with winter wheat on an acidic podzol section of low fertility. Before the pre-sowing cultivation various doses of ground limestone, from 10 tons to 3 centners per ha., were introduced into the soil in pure form, combined with superphosphate (3 centners per ha.) and mixed with 1.8 tons of an organic fertilizer—humus.

In the spring of 1953, after the whole wheat field had been given 1 centner per ha. of ammonium nitrate as extra nutrition, all the plots were sown with clover mixed with timothy. The experiment was launched with two duplications of it.

Variations in the fertilizer combinations are indicated in Table 1.

In going over the data contained in Table 1, we call par-

ticular attention to the variation in which 1.8 tons of humus were mixed with 3 centners of ground limestone. The seed yield obtained from the plot on which this variation was tested was 9.5 centners in excess of the yield of the control (unfertilized) plot. It was also higher than that of variations in which 5 tons and 10 tons of ground limestone had been introduced, both with (3 centners) and without superphosphate.

It must be noted that the soil of the experimental section was podzolic, of high acidity (pH approximately 4) and it therefore reacted well to the lime applied.

Table 1

Influence of Various Fertilizers on Yields of Winter Wheat and Clover

Amount of fertilizer introduced per ha. in autumn 1952 before winter wheat sowing	Wheat grain yield in 1953 (in centners per ha.)	Clover hay yield in 1954 (in centners per ha.)
10 tons ground limestone	22.2	42.7
10 tons ground limestone + 3 centners superphosphate	24.0	42.7
5 tons ground limestone	22.6	42.7
5 tons ground limestone + 3 centners superphosphate	25.2	45.3
Control	17.8	34.7
1.8 tons humus	24.1	44.0
1.8 tons humus + 3 centners superphosphate	27.4	46.7
3 centners superphosphate	22.0	40.7
1.8 tons humus + 3 centners superphosphate + 3 centners ground limestone	28.7	52.0
3 centners ground limestone	19.9	36.7
1.8 tons humus + 3 centners ground limestone	27.3	49.3

We call attention to the fact that in the experiment under analysis the efficacy of 1.8 tons of humus mixed with 3 centners of superphosphate (crop yield 27.4 centners of grain per ha.) proved equal to the efficacy of 1.8 tons of humus mixed with 3 centners of ground limestone (crop yield 27.3 centners of grain per ha.). Naturally, calcium could not replace phosphorus. Therefore we may well suppose that in the present case the superphosphate was effective not so much owing to the phosphorus as to its calcium.

From the data contained in the table we may draw the conclusion that more mineral and nitrogenous nutritive substances were taken from the soil with the crop than were introduced into it in the shape of fertilizers. This is particularly obvious in the variation of the experiment in which 1.8 tons of humus mixed with 3 centners of ground limestone were applied. In that case 6 centners of organic matter in air-dry condition were introduced (the humus applied had a moisture content of about 70 per cent), and the additional yield of grain alone was equal to 9.5 centners per ha. compared with the unfertilized plot. A kilogramme or centner of air-dry wheat grain is, in ash element and nitrogen content, not poorer but richer than a kilogramme or centner of air-dry organic fertilizer (humus) applied to the soil.

In 1954 clover mixed with timothy was grown on that experimental section. The after-effect of the fertilizer applied in the autumn of 1952 to the soil under wheat on the development of clover made itself felt no less than the action of the fertilizer the preceding year. The air-dry clover hay crop yield and the different variations of that experiment in 1954 are registered in the same table.

As we see, the clover hay crop in the variation practised on the plot into which 1.8 tons of humus mixed with 3 centners of ground limestone per ha. were introduced in the autumn of 1952, is 14.6 centners bigger than the crop on the unfertilized control plot. The clover hay yield from the specified experimental plot is also not less than that from the

plots fertilized with 5 and 10 tons (per ha.) of ground limestone without organic fertilizer.

If we were to add to the 9.5 centners of wheat grain, obtained in 1953 in the shape of excess yield from the plot of the experimental variation indicated, the 14.6 centners of air-dry clover hay obtained in 1954 from that plot, likewise in the shape of excess yield, then everyone would clearly see that in the present case the plants took from the soil considerably more nutrients than the fertilizers had introduced.

Was the soil depleted of nutritives as the result of such a large withdrawal?

The clover and timothy stood the winter well in 1954-55, and there is reason to suppose that the difference in the hay crop in favour of the experimental variation during the second year of the utilization of grasses will be no less, in comparison with the control figures, than it was during the first year of the utilization of grasses.

It is likewise clear to every agricultural worker that after two years of grass utilization there will be considerably more stubbles and roots, i.e., organic substances, on the experimental plot indicated than on the control plot. And I do not think I am mistaken if I maintain that the difference in weight of the organic substances in the soil between the experimental and the control plot will likewise be greater than the weight of the organic fertilizers employed in 1952 on the above experimental plot.

It is also evident that on the plot that had a good wheat crop followed by two years of good clover crops mixed with timothy, any crop will develop better without fertilizer than on the control plot, where the wheat and clover yields were lower.

The data quoted are obvious proof of the erroneousness of the theory of "take and return." That is clearly demonstrated by this concrete experiment. The greater the yield and the more nutritive matter is taken from the soil in the form of the crop, the more its fertility increases; it becomes richer in nutritive matter, in organic matter.

Such experiments show that, in taking alimentation from the soil, plants may, despite the theory of "take and return," not exhaust but on the contrary enrich the soil, and the higher the yield obtained the more the soil's fertility increases. This does not mean, of course, that in practice fertilizers should not be used year after year. Fertilization must be practised every year on every field, particularly in the podzol zone, no matter to what crop it is put, but such fertilization methods must and can be found as will require a minimum expenditure of energy and means.

The way to get there is not so much to feed the plants directly on the fertilizers applied as to activize the biological process of converting the elements of inorganic nature into plant food.

Let us quote also the data supplied by one of the 1954 Gorki Leninskiye experiments. Unfertile acidic podzol was picked for this experiment. The fertilizer mixture was put on at the per ha. rate of 4-6 tons of decomposed manure mixed with 2 centners of superphosphate and 3 centners of ground limestone. In this experiment fertilizers were tested on a number of field and vegetable crops. The efficacy of the fertilizers proved good.

Beans on unfertilized plots produced 6.9 kg. of mature seeds per plot; on fertilized plots, 9.2 kg. Another variety of beans produced, without fertilizer, 4.5 kg. of mature seeds per plot; with fertilizer, 7.4 kg.

Hybrid maize VIR-42 produced on the average 14.1 tons of green silage per ha. on unfertilized plots; on fertilized plots, 23.4 tons.

Cabbage, Slava variety, planted in beds 70×70 cm., produced without peat-compost pots and without fertilizer an average of 113 centners per ha.; with fertilizer, 296 centners.

Sunflower plants produced an average of 15.1 tons of green silage per ha. without fertilizer; with fertilizer, 21.2 tons.

Of special interest are the results obtained in the cucumber experiments. On the unfertile acidic section, assigned to

them, the cucumber plants got along very badly without fertilizer. One unfertilized plot yielded 2 tons per ha., another 1.7 tons. Putting ground limestone into the sowing pockets did not raise the yield. Putting in superphosphate induced a slight yield increase—to 4.7 tons per ha. But, of course, such a yield is also too low. However, when the organic-phosphoric limestone mixture was introduced into the pockets, the cucumber yield jumped to 20.9 and even 25 tons a hectare.

This cucumber experiment is a palpable proof that a section of land that will bear almost no cucumbers at all may yield a quite handsome crop if a mere 4-6 tons of organic-phosphoric-limestone mixture per ha. are applied.

I shall also adduce the results of the potato experiments. The tubers picked for planting were of the Priekuli variety from last year's summer-planted harvest. Every tuber was cut in half lengthwise. One half was planted in a hill without fertilizer, the other in the next furrow in a hill fertilized with the above-indicated mixture. The harvest of each hill was reaped separately. In all cases without exception the fertilized hills registered tuber yields 30-50 per cent higher than those of the unfertilized hills.

In all the above crops (and in a number of others we did not specify here), the fertilizer mixture was introduced into the sowing pockets. Of still greater interest are the results of this same experiment with such crops as buckwheat, flax and fodder beetroots, for in these cases the fertilizer mixture was not put on the rows or into the pockets together with the seeds but was broadcast, scattered superficially before the sowing, the fertilizers being worked in by the cultivator.

In this experiment 9.5 centners of buckwheat grain were obtained per ha. without fertilizer and 13.9 centners with fertilizer. Of long-fibre flax seeds 2.8 centners were obtained without fertilizer and 4.2 centners with fertilizer. The fodder-beetroot crop was on the average only 20.8 centners without fertilizer, but 143.2 centners with fertilizer.

All these experiment data were obtained on acidic podzol soil of low fertility.

For purposes of comparison let me state that on introducing approximately the same fertilizer doses in the same year, 1954, not on a sector that was barren, as far as a crop like cucumbers was concerned, but on the best cultivated piece of land (an area of 2 ha.), the Gorki Leninskiye farm secured a yield of bedded cucumbers amounting to 55 tons per ha. On sections fertilized the same way, the farm gathered in per ha. 347 centners of early cabbage, about 500 centners of maize silage, over 400 centners of sugar beetroots, etc.

The action of fertilizers on winter wheat yields in sections of various degrees of fertility (see Table 2) is also of interest. The soil fertility of the sections cited in the table can be gauged by the yields of the control plots. In the spring of 1954 ammonium nitrate was applied to all the plots, including control plots, as nitrogenous extra nutrition at the rate of 1 centner per ha.

As the different sections of the farm differed in fertility, every fertilized plot had an unfertilized control plot alongside of it. Therefore the action of the different kinds of fertilizers (see Table 2) has to be compared either with that on the control plot adjoining it or with that on two control plots: one next to the experimental plot and another plot further. The plots measured 500 sq. m. on two fields and 450 sq. m. on one field.

The fertilizers and their mixtures were hand-sown on the plots, and were covered up by the general disking and harrowing before the sowing.

Table 2 indicates that the less fertile the soil and the lower the wheat grain yield of the control plots, the greater the effect of introducing fertilizer. If we calculate on each section the average yield of the control plots and separately the average yield of the plots that had been dressed with mineral fertilizers, which include the plot fertilized with ground limestone only, and also ascertain the average yield

Table 2

Effect of Fertilizers on Winter Wheat Yields in Sections Differing in Fertility

No. of plot	Kind of fertilizer and amount per ha.	Yield of winter-wheat grain after fallow (in centners per ha.)	Yield of winter-wheat grain after winter wheat (in centners per ha.)	Yield of winter-wheat grain after vetch-oats (in centners per ha.)
1	3 tons humus	18.50	22.18	32.80
2	Control	16.24	22.78	33.00
3	3 tons humus + 2 centners superphosphate	20.86	25.74	34.30
4	2 centners superphosphate	18.52	26.44	34.10
5	Control	13.76	23.20	34.70
6	3 tons humus + 2 centners superphosphate + 3 centners ground limestone	22.14	22.00	35.90
7	2 centners superphosphate + 3 centners ground limestone	17.98	21.00	36.00
8	Control	14.76	16.04	34.10
9	3 tons humus + 1 centner superphosphate + 2 centners ground phosphorite	20.68	20.56	32.50
10	1 centner superphosphate + 2 centners ground phosphorite	17.66	20.76	34.00
11	Control	11.46	19.90	33.20
12	3 tons humus + 1 centner superphosphate + 2 centners ground phosphorite + 3 centners ground limestone	19.06	24.56	31.60
13	1 centner superphosphate + 2 centners ground phosphorite + 3 centners ground limestone	16.24	22.86	34.50
14	Control	11.54	21.46	32.40
15	3 tons humus + 3 centners ground phosphorite	17.06	22.44	33.40
16	3 centners ground phosphorite	15.20	22.60	31.00

Continued

No. of plot	Kind of fertilizer and amount per ha.	Yield of winter-wheat grain after fallow (in centners per ha.)	Yield of winter-wheat grain after winter wheat (in centners per ha.)	Yield of winter-wheat grain after vetch-oats (in centners per ha.)
17	Control	10.80	22.08	31.20
18	3 tons humus + 3 centners ground limestone	17.80	22.50	32.10
19	3 centners ground limestone	11.90	21.56	33.10
20	Control	4.90	20.84	31.70
21	3 tons humus + 3 centners ground phosphorite + 3 centners ground limestone	12.20	22.36	31.70
22	3 centners ground phosphorite + 3 centners ground limestone	10.50	21.26	30.60

of all plots where organic fertilizer was applied—3 tons in pure form and also mixed with various minerals such as phosphorites and ground limestone, we obtain the following figures, all yields being calculated per ha:

1. *On the fallow field* the average yield of the control plots was 11.9 centners, the average yield of the plots dressed with mineral fertilizers—15.4 centners, and of the plots dressed with organic fertilizers mixed with mineral fertilizers—18.5 centners.

2. *On the field where winter wheat followed winter wheat*, the yield of the control plots was 20.9 centners, of the plots dressed with mineral fertilizers—22.3 centners, and of the plots dressed with organic fertilizers mixed with mineral fertilizers—22.8 centners.

3. *On the well cultivated section*, where the preceding crop had been a mixture of vetch and oats, the average yield of the control plots was 32.9 centners, of the plots into

which mineral fertilizers had been introduced—33.3 centners, and of the plots into which organic fertilizers mixed with mineral ones had been introduced—33.0 centners.

The soil of the last section was well cultivated and, as we see from Table 2, no yield increase ensued from the application of fertilizer. In that case the size of the yield on this section of 2.5 ha. was determined by the variety sown; for when organic-phosphoric-limestone mixture was used there and a different variety of winter wheat was sown, the grain yield obtained by the farm was 42 centners per ha.

Highly interesting data were supplied by the section where winter wheat followed winter wheat. It was a section of little fertility, 11.5 ha. in size. In the autumn of 1952, after a biennial clover crop mixed with timothy had been ploughed up, the section was sown to winter wheat. On 1.5 ha. no fertilizer was applied before the winter wheat sowing. In 1953, 10 centners of grain were obtained per ha. Right next to it, on a 1-hectare plot, 3 centners of powdered superphosphate were applied prior to the pre-sowing cultivation and before the winter wheat was sown. The yield was 14.6 centners per ha. On 2.7 ha. next to the plot manured with pure superphosphate, organic-phosphoric-limestone composts were introduced before the pre-sowing cultivation. This section yielded 21 centners per ha. The remaining land, 6.3 ha., lying next to a wholly unfertilized section, received a dressing of 3 centners of superphosphate mixed with 1.5 tons of humus. The resultant wheat grain yield was 23.4 centners per ha.

After the 1953 harvest the entire section was ploughed up and in the autumn of the same year was again sown to winter wheat. On that part which in 1952 had been manured with a mixture of 1.5 tons of humus and 3 centners of superphosphate per ha., plots were laid out whose yields in 1954 are indicated in Table 2, according to the fertilizer used. These 1954 plot yields indicate, I believe, that the soil has improved as a result of the use of fertilizers for the preceding winter wheat and of the satisfactory crop—23.4

centners of wheat grain per ha. This alone can explain why the yield of the control plots, which had not been fertilized before the 1954 sowing, (see Table 2) was satisfactory—21.2 centners per ha. on the average. The fertilized variations had a small increase in yield.

Fertilization had its greatest effect on the uncultivated section, which before the wheat-sowing looked like unfertilized fallow.

A vast amount of factual material has already been accumulated. It goes to show the expediency of applying organic-phosphoric-limestone mixtures to acidic podzol soils and of organic-phosphoric mixtures on non-acidic soils. The use of small doses of these fertilizer mixtures, which should be worked into the soil at a small depth, clearly testify to the fact, if we go by the handsome yield increases, that the introduction of these fertilizers revives, activizes the soil microflora beneficial to agricultural plants. As a result of the intensification of the vital activity of the soil micro-organisms, there has been achieved a considerable improvement in the process of the soil nutrition of plants by converting unassimilable forms of chemical elements and their soil compounds as well as gaseous nitrogen into forms that can be assimilated.

Factual data on the application of the fertilizers mentioned above have been procured not only in the experiments conducted by the Academy's Gorki Leninskiye experimental farm. Such experiments were performed also by many other scientific agricultural institutions as well as by numerous collective and state farms. In the autumn of 1954, in pursuance of a government decision, organic-phosphoric-limestone mixtures were experimentally applied before sowing on almost all collective and state farms of Moscow Region. In Moscow Region winter-wheat fields occupying more than 70,000 ha. were fertilized in the manner indicated. Collective and state farms in other regions made similar production experiments.

In general, the problems of field fertilization, of finding

the most rational methods of fertilization, should be studied from the angle of establishing the best conditions for stimulating the vital activity of the beneficial soil microflora and for suppressing the noxious microflora. This is the criterion by which to select in each particular case both the fertilizer components and the quantities to be used of each, as well as the time and method of putting the fertilizer into the soil. When applying bacterial fertilizers, the conditions that favour the bacteria development in the soil must be created.

Enzymic research into the soil nutrition of plants must be considerably intensified. In addition to studying the chemistry of mineral soils it is highly essential to develop the so-called enzymic chemistry (biochemistry). As I see it, the enzymic processes going in the soil play the leading part. Yet the enzymic chemistry of the soil (biochemistry) is still a lagging department of agronomic chemistry.

The intricate biological interconnections in the soil, the interconnections between plant roots and soil micro-organisms, and through them between the inaccessible minerals of the soil and the elements of the atmosphere, must be elaborated with particular attention by the various departments of agronomic and biological science.